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NEW SOUTH WALES
FOR
1933
(INCORPORATED 1881)

VOL. LXVII
Parts I and II

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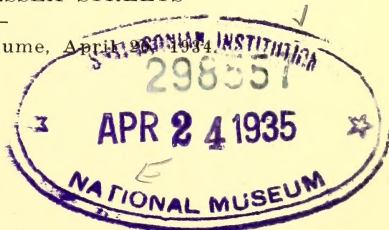
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SYDNEY
PUBLISHED BY THE SOCIETY, SCIENCE HOUSE
GLOUCESTER AND ESSEX STREETS

Issued as a complete volume, April 1934

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NOTICE.

THE ROYAL SOCIETY of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society", by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

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Authors should submit their papers in typescript and in a condition ready for printing. All physico-chemical symbols and mathematical formulæ should be so clearly written that the compositor should find no difficulty in reading the manuscript. Sectional headings and tabular matter should not be underlined. Pen-illustrations accompanying papers should be made with black Indian ink upon smooth white Bristol board. Lettering and numbers should be such that, when the illustration or graph is reduced to $3\frac{1}{2}$ inches in width, the lettering will be quite legible. On graphs and text figures any lettering may be lightly inserted in pencil. Photomicrographs should be rectangular rather than circular, to obviate too great a reduction. The size of a full page plate in the Journal is $4 \times 6\frac{1}{4}$ inches, and the general reduction of illustrations to this limit should be considered by authors. When drawings, etc., are submitted in a state unsuitable for reproduction, the cost of the preparation of such drawings for the process-block maker must be borne by the author. The cost of colouring plates or maps must also be borne by the author.

CORRIGENDUM.

The figure-titles on pp. 35 and 43 are correctly placed, but the maps should be transposed.

FORM OF BEQUEST.

I bequeath the sum of £ to the ROYAL SOCIETY
of NEW SOUTH WALES, Incorporated by Act of the Parliament
of New South Wales in 1881, and I declare that the receipt of
the Treasurer for the time being of the said Corporation shall
be an effectual discharge for the said Bequest, which I direct
to be paid within calendar months after my
decease, without any reduction whatsoever, whether on account
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estate as may be lawfully applied for that purpose.

[Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.]

PUBLICATIONS.

The following publications of the Society, if in print, can be obtained at the Society's Rooms, Science House, Gloucester and Essex Streets, Sydney.

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

Vols. I-XI Transactions of the Royal Society, N.S.W., 1867-1877 „

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*Resigned 28th February, 1934, succeeded by E. H. BOOTH, M.C., B.Sc., F.Inst. P.

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LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales

P Members who have contributed papers which have been published in the Society Journal. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.

| | | |
|------|------|--|
| 1908 | | Abbott, George Henry, B.A., M.B., Ch.M., 185 Macquarie-street; p.r. "Cooringa," 252 Liverpool Road, Summer Hill. |
| 1904 | | Adams, William John, M.I.Mech.E., 175 Clarence-street. |
| 1898 | | Alexander, Frank Lee, William-street, Granville. |
| 1905 | P 3 | Anderson, Charles, M.A., D.Sc. <i>Edin.</i> , Director of the Australian Museum, College-street. (President, 1924.) |
| 1909 | P 10 | Andrews, Ernest C., B.A., F.G.S., Hon. Mem. Washington Academy of Sciences, 32 Benelong Crescent, Bellevue Hill. (President, 1921.) |
| 1933 | | Andrews, John, B.A., Demonstrator in Geography in the University of Sydney; p.r. "Avalon," Neret-street, Hunter's Hill. |
| 1930 | | Aston, Ronald Leslie, D.Phil., B.Sc., B.E. <i>Syd.</i> , M.Sc. <i>Cantab.</i> , Lecturer in Civil Engineering and Surveying in the University of Sydney, 24 Redmyre-road, Strathfield. |
| 1919 | | Arousseau, Marcel, B.Sc., No. 65A Market-lane, Manly. |
| 1923 | | Baccarini, Antonio, Doctor in Chemistry, <i>Florence</i> , c/o Dante Alighieri Society, Box 1168, G.P.O., Sydney. |
| 1878 | | Backhouse, His Honour Judge A.P., M.A., "Melita," Elizabeth Bay. |
| 1924 | P 1 | Bailey, Victor Albert, M.A., D.Phil., F.Inst.P., Assoc.-Professor of Physics in the University of Sydney. |
| 1919 | | Baker, Henry Herbert, Watson House, Bligh-street, Sydney. |
| 1894 | P 28 | Baker, Richard Thomas, The Crescent, Cheltenham. |
| 1919 | | Bardsley, John Ralph, 76 Wright's-road, Drummoyne. |
| 1925 | | Barker-Woden, Lucien, F.R.G.S., Commonwealth Department of Navigation, William-street, Melbourne. |

Elected.

| | | |
|------|------|--|
| 1895 | P 9 | Barracrough, Sir Henry, K.B.E., B.E., M.M.E., M.Inst.C.E., M.I.Mech.E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Dean of the Faculty of Engineering and Professor of Mechanical Engineering in the University of Sydney. |
| 1929 | | Baur, Fidel George, M.D., Ophthalmic Surgeon, 213 Macquarie-street, Sydney. |
| 1933 | | Bedwell, Arthur Johnson, Eucalyptus Oil Merchant, "Kama," No. 10 Darling Point-road, Edgecliff. |
| 1909 | P 2 | Benson, William Noel, D.Sc. <i>Syd.</i> , B.A. <i>Cantab.</i> , F.G.S., Professor of Geology in the University of Otago, Dunedin, N.Z. |
| 1926 | | Bentivoglio, Sydney Ernest, B.Sc.Agr., c/o Tooth and Co., Limited, Sydney; p.r., 14 Gordon-avenue, Coogee. |
| 1919 | | Bettley-Cooke, Hubert Vernon, F.C.S., A.A.C.I., "The Hollies," Minter-street, Canterbury. |
| 1923 | | Birks, George Frederick, c/o Potter & Birks, 15 Grosvenor-street, Sydney. |
| 1916 | | Birrell, Septimus, Appian Way, Burwood. |
| 1920 | | Bishop, Eldred George, 8 Belmont-road, Mosman. |
| 1915 | | Bishop, John, 12 O'Connell-street, Sydney. |
| 1923 | P 4 | Blakely, William Faris, "Myola," Florence-street, Hornsby. |
| 1905 | | Blakemore, George Henry, "Wawoona," 10 Cooper-street, Strathfield. |
| 1888 | † | Blaxland, Walter, F.R.C.S. <i>Eng.</i> , L.R.C.P. <i>Lond.</i> , "Inglewood," Florida-road, Palm Beach, Sydney. |
| 1933 | | Boan, Robert Farquhason, Analyst and Consulting Chemist, 232 Clarence-street, Sydney. |
| 1933 | P 2 | Bolliger, Adolph, Ph.D., Director of Research; p.r. 9A Carr-street, Coogee. |
| 1926 | P 5 | Booker, Frederick William, B.Sc., "Dunkeld," Nicholson-street, Chatswood. |
| 1932 | | Boon, Herbert Eril, Clerk, University Student and Geologist, 109 Darley-road, Randwick. |
| 1920 | P 5 | Booth, Edgar Harold, M.C., B.Sc., F.Inst.P., Lecturer and Demonstrator in Physics in the University of Sydney. |
| 1922 | | Bradfield, John Job Crew, C.M.G., D.Sc. <i>Eng.</i> , M.E., M.Inst.E. <i>Aust.</i> , 23 Park-avenue, Gordon. |
| 1926 | | Branch, Kenneth James F., 99 Ocean Beach, Manly. |
| 1917 | | Breakwell, Ernest, B.A., B.Sc., Dept. of Education, Box 33A, G.P.O., Sydney. |
| 1891 | | Brennand, Henry J. W., B.A., M.D., Ch.M. <i>Syd.</i> , V.D., Surgeon Commander R.A.N. Ret., 223 Macquarie-street; p.r. 73 Milsons-road, Cremorne. |
| 1919 | P 1 | Briggs, George Henry, B.Sc., Ph.D., Assistant-Professor of Physics in the University of Sydney. |
| 1923 | | Brown, Herbert, "Sikoti," Alexander-street, Collaroy Beach, Sydney. |
| 1906 | | Brown, James B., St. Andrew's, No. 1 Maitland-avenue, East Kew, E.4, Victoria. |
| 1913 | P 20 | Browne, William Rowan, D.Sc., Assistant-Professor of Geology in the University of Sydney. Vice-President. (President, 1932.) |
| 1898 | † | Burfitt, W. Fitzmaurice, B.A., M.B., Ch.M., B.Sc. <i>Syd.</i> , "Wyoming," 175 Macquarie-street, Sydney. |

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| Elected. | | |
| 1926 | | Burkitt, Arthur Neville St. George, M.B., B.Sc., Professor of Anatomy in the University of Sydney. |
| 1919 | P 10 | Burrows, George Joseph, B.Sc., Lecturer and Demonstrator in Chemistry in the University of Sydney; p.r. Watson-street, Neutral Bay. |
| 1929 | | Caley, Gilbert Fatkin, Manager, Matthews & Wilson (1931) Ltd., Manufacturing Chemists, 6 and 8 Cole-street, Borough, London, England. |
| 1929 | P 1 | Callaghan, Allan Robert, D.Phil., B.Sc. <i>Oxon.</i> , Principal, Roseworthy Agricultural College, Adelaide, S.A. |
| 1909 | | Calvert, Thomas Copley, Assoc.M.Inst.C.E., c/o Messrs. T. Michell & Gee, 92 Pitt-street, Sydney. |
| 1923 | | Cameron, Lindsay Duncan, Hilly-street, Mortlake. |
| 1891 | | Carment, David, F.I.A. <i>Grt. Brit. and Irel.</i> , F.F.A. <i>Scot.</i> , 4 Whaling-road, North Sydney. |
| 1903 | P 3 | Carslaw, Horatio S., M.A., Sc.D., Professor of Mathematics in the University of Sydney. |
| 1913 | P 3 | Challinor, Richard Westman, F.I.C., F.C.S., Lecturer in Chemistry, Sydney Technical College; p.r. 53 Drumalbyn-road, Bellevue Hill. (President.) |
| 1933 | | Chalmers, Robert Oliver, A.S.T.C., Assistant (Professional) in Mineralogy, Australian Museum, College-street, Sydney. |
| 1909 | P 2 | Chapman, Henry G., M.D., B.S., Director of Cancer Research, University of Sydney. (Hon. Treasurer.) |
| 1913 | P 19 | Cheel, Edwin, Curator, National Herbarium, Botanic Gardens, Sydney. (Vice-President.) (President, 1931.) |
| 1925 | P 1 | Clark, William E., High School, Armidale. |
| 1920 | | Cooke, Frederick, c/o Meggitt's Limited, Asbestos House, York and Barrack-streets, Sydney. |
| 1913 | P 4 | Coombs, F. A., F.C.S., Instructor of Leather Dressing and Tanning, Sydney Technical College; p.r. Bannerman-crescent, Rosebery. |
| 1928 | | Coppleson, Victor Marcus, M.B., Ch.M., F.R.C.S., 225 Macquarie-street, Sydney. |
| 1933 | | Corbett, Robert Loriner, Managing Director of Robert Corbett & Co., Manufacturing Chemists, 379 Kent-street, Sydney. |
| 1882 | | Cornwell, Samuel, J.P., "Capanesk," Tyagarah, North Coast. |
| 1919 | | Cotton, Frank Stanley, M.Sc., Chief Lecturer and Demonstrator in Physiology in the University of Sydney. |
| 1909 | P 7 | Cotton, Leo Arthur, M.A., D.Sc., Professor of Geology in the University of Sydney. (Vice-President.) (President, 1929.) |
| 1892 | P 1 | Cowdery, George R., Assoc.M.Inst.C.E., Strathfield-avenue, Strathfield. |
| 1886 | | Crago, W. H., M.R.C.S. <i>Eng.</i> , L.R.C.P. <i>Lond.</i> , 135 Macquarie-street. |
| 1921 | P 1 | †Cresswick, John Arthur, 101 Villiers-street, Rockdale. |
| 1925 | | Curry, Harris Eric Marshall, 89 Ridge-street, North Sydney. |

Elected.

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| 1912 | | Curtis, Major Louis Albert, L.S., F.I.S. <i>N.S.W.</i> , v.d., Room 618, Government Savings Bank Building, Castlereagh-street; p.r. No. 1 Mayfair Flats, Macleay-street, Darlinghurst. |
| 1890 | | Dare, Henry Harvey, M.E., M.Inst.C.E., Commissioner, Water Conservation and Irrigation Commission, Department of Agriculture Building, Raphael-street, Sydney. |
| 1886 | P 23 | David, Sir Edgeworth, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., Wollaston Medallist, Emeritus Professor of Geology and Physical Geography in the University of Sydney; p.r. "Coringah," Burdett-street, Hornsby. (President, 1895, 1910.) |
| 1928 | | Davidson, Walter Charles, General Manager, Clyde Engineering Company, Granville. |
| 1930 | | Davies, Harold Whitridge, M.B., B.S. <i>Adel.</i> , Professor of Physiology in the University of Sydney. |
| 1919 | P 2 | de Beuzeville, Wilfrid Alex. Watt, J.P., "Mélamere," Welham-street, Beecroft. |
| 1921 | | Delprat, Guillaume Daniel, C.B.E., "Keynsham," Mandeville-crescent, Toorak, Victoria. |
| 1894 | | Dick, James Adam, C.M.G., B.A. <i>Syd.</i> , M.D., Ch.M., F.R.C.S. <i>Edin.</i> , "Catfoss," 59 Belmore-road, Randwick. |
| 1906 | | ‡Dixon, William, "Merridong," Gordon-road, Killara. |
| 1913 | P 3 | Doherty, William M., F.I.C., F.C.S., Atlas Building, 8 Spring-street, Sydney; p.r. "Jesmond," George-street, Marrickville. |
| 1928 | | Donegan, Henry Arthur James, A.S.T.C., Chemical Laboratory, Department of Mines, Sydney. |
| 1908 | P 6 | Dun, William S., Palæontologist, Geology Department, University of Sydney; p.r. 11 Clanalpine-street, Mosman. (President, 1918.) |
| 1924 | | Dupain, George Zephirin, A.A.C.I., F.C.S., Dupain Institute of Physical Education, Manning Building, Pitt and Hay-streets, Sydney; p.r. "Rose Bank," 158 Parramatta-road, Ashfield. |
| 1924 | | Durham, Joseph, Judge-street, Randwick. |
| 1923 | P 13 | Earl, John Campbell, D.Sc., Ph.D., Professor of Organic Chemistry in the University of Sydney. |
| 1924 | | Eastaugh, Frederick Alldis, A.R.S.M., F.I.C., Associate Professor in Chemistry, Assaying and Metallurgy in the University of Sydney. |
| 1916 | P 2 | Enright, Walter J., B.A., High-street, West Maitland, N.S.W. |
| 1908 | | Esdaile, Edward William, 42 Hunter-street. |
| 1921 | | Farnsworth, Henry Gordon, "Rothsay," 90 Alt-street, Ashfield. |

Elected.

| | | |
|------|-----|--|
| 1910 | | Farrell, John, A.T.C. <i>Syd.</i> , Riverina Flats, 265 Palmer-street, Sydney. |
| 1909 | P 7 | Fawsitt, Charles Edward, D.Sc., Ph.D., Professor of Chemistry in the University of Sydney. (President, 1919.) |
| 1922 | | Ferguson, Andrew, B.Sc., 22 Village Lower-rd., Vacluse. |
| 1927 | P 3 | Finnemore, Horace, B.Sc., F.I.C., Lecturer in Pharmacy in the University of Sydney. |
| 1923 | | Fiaschi, Piero, O.B.E., M.D. <i>Columbia Univ.</i> , D.D.S. <i>New York</i> , M.R.C.S. <i>Eng.</i> , L.R.C.P. <i>Lond.</i> , 178 Phillip-street. |
| 1920 | | Fisk, Ernest Thomas, Wireless House, 47 York-street. |
| 1888 | | Fitzhardinge, His Honour Judge G. H., M.A., "Red Hill," Pennant Hills. |
| 1933 | | Fletcher, Harold Oswald, Assistant Palæontologist, Australian Museum, College Street, Sydney. |
| 1879 | | †Foreman, Joseph, M.R.C.S. <i>Eng.</i> , L.R.C.P. <i>Edin.</i> , "The Astor," Macquarie-street. |
| 1932 | | Forman, Kenn. P., M.I.Refr.E., Electricity Meter Mfg. Co., Ltd., Waterloo; p.r. 49 Coogee Bay-road, Randwick. |
| 1920 | | Fortescue, Albert John, "Benambra," Loftus-street, Arncliffe |
| 1905 | | Foy, Mark, Liverpool and Elizabeth-streets, Sydney. |
| 1925 | | Friend, Norman Bartlett, 48 Pile-street, Dulwich Hill. |
| 1933 | P 1 | Frost, Herbert John, M.Sc. <i>Syd.</i> , 20 Aboud-avenue, South Kensington. |
| 1918 | | Gallagher, James Laurence, M.A. <i>Syd.</i> , "Akaroa," Ellesmere-avenue, Hunter's Hill. |
| 1926 | | Gibson, Alexander James, M.E., M.Inst.C.E., M.I.E. <i>Aust.</i> , 906 Culwulla Chambers, Castlereagh-street, Sydney. |
| 1921 | | Godfrey, Gordon Hay, M.A., B.Sc., Lecturer in Physics in the Technical College, Sydney; p.r. "Eversham," Victoria-parade, Manly. |
| 1897 | | Gould, The Hon. Sir Albert John, K.B., V.D., "Eynesbury," Edgecliff-road, Edgecliff. |
| 1932 | | Goulder, Francis, A.S.T.C., A.A.C.I., Manager, Ever-Ready Works, Marshall-street, Surry Hills, Sydney. |
| 1922 | P 2 | Greig, William Arthur, Mines Department, Sydney. |
| 1880 | P 5 | Halligan, Gerald H., L.S., F.G.S., "Alameda," Challis-avenue, Turramurra. |
| 1912 | | Hallmann, E. F., B.Sc., 15 Harrington-street, Mar-rickville. |
| 1892 | | Halloran, Henry Ferdinand, L.S., 82 Pitt-street. |
| 1919 | | Hambridge, Frank, Adelaide Steamship Co. Chambers, 22 Bridge-street, Sydney. |
| 1912 | | Hamilton, Alexander G., "Tanandra," Hercules-street, Chatswood. |
| 1909 | | Hammond, Walter L., B.Sc., High School, Broken Hill. |
| 1933 | | Hancock, Francis Charles, B.Sc. (Hons.), Dip.Ed. (<i>University of Bristol</i>), Cranbrook School, Edgecliff. |
| 1905 | P 5 | Harker, George, D.Sc., F.A.C.I., 57 Junction-street, Summer Hill. |

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| 1913 | P 1 | Harper, Leslie F., F.G.S., Government Geologist, Department of Mines, Sydney. |
| 1923 | P 2 | Harrison, Travis Henry, B.Sc.Agr., Lecturer in Botany and Entomology at the Hawkesbury Agricultural College, Richmond. |
| 1918 | | Hassan, Alex. Richard Roby. |
| 1929 | | Hawley, Joseph William, 15 Springdale-road, Killara. |
| 1914 | | Hector, Alex. Burnet, "Drumindard," Greenwich-road, Greenwich. |
| 1916 | | Henderson, James, "Dunsfold," Clanalpine-street, Mosman. |
| 1919 | | Henriques, Frederick Lester, 208 Clarence-street. |
| 1919 | P 2 | Henry, Max, D.S.O., B.V.Sc., M.R.C.V.S., Chief Veterinary Surgeon, Dept. Agriculture, Sydney; p.r. "Coram Cottage," Essex-street, Epping. |
| 1918 | | Hindmarsh, Percival, M.A., B.Sc.Agr., Agricultural High School, Yanco. |
| 1921 | P 2 | Hindmarsh, William Lloyd, B.V.Sc., M.R.C.V.S., D.V.H., District Veterinary Officer, Glenfield. |
| 1928 | | Hirst, George Walter Cansdell, B.Sc., Power and Mechanical Branch, Department of Transport for N.S.W., Wilson-street, Redfern; p.r. "St. Cloud," Beaconsfield-road, Chatswood. |
| 1930 | | Hodson, John S., Electrical Engineer, H.M. Naval Establishments, Garden Island, Sydney. |
| 1916 | | Hoggan, Henry James, A.M.I.M.E., A.M.I.E. <i>Aust.</i> ; p.r. "Lincluden," Frederick-street, Rockdale. |
| 1924 | | Holme, Ernest Rudolph, O.B.E., M.A., Professor of English Language in the University of Sydney. |
| 1930 | | Holmes, James MacDonald, Associate Professor of Geography in the University of Sydney. |
| 1901 | | Holt, Thomas S., "Amalfi," Appian Way, Burwood. |
| 1905 | P 3 | Hooper, George, J.P., F.S.T.C. <i>Syd.</i> , "Myeumbene," Nielsen Park, Vacluse. |
| 1919 | | Hoskins, Arthur Sidney, Steel Works, Port Kembla; postal address, P.O. Box 36, Wollongong. |
| 1919 | | Hoskins, Cecil Harold, c/o Australian Iron and Steel Co., Ltd., Kembla Building, Margaret-street, Sydney. |
| 1913 | | Hudson, G. Inglis, J.P., F.C.S., 55 Wunulla-road, Woollahra Point. |
| 1923 | P 2 | †Hynes, Harold John, M.Sc., B.Sc.Agr., Senior Asst. Biologist, Department of Agriculture, Sydney. |
| 1922 | | Jacobs, Ernest Godfried, "Cambria," 106 Bland-street, Ashfield. |
| 1904 | | Jaquet, John Blockley, A.R.S.M., F.G.S., 6 Treatt's-road, Lindfield. |
| 1929 | | Jeffrey, Robert Ewen, A.A.C.I., Managing Director, Bardsley's Ltd.; p.r. 9 Greycliffe-avenue, Vacluse. |
| 1925 | | Jenkins, Charles Adrian, B.E., B.Sc., 2 Ramsgate-avenue, Bondi Beach. |
| 1917 | | Jenkins, Richard Ford, Engineer for Boring, Irrigation Commission, 6 Union-street, Mosman. |

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| 1909 | P 15 | Johnston, Thomas Harvey, M.A., D.Sc., F.L.S., C.M.Z.S., Professor of Zoology in the University of Adelaide. (Cor. Mem., 1912.) |
| 1924 | | Jones, Leo Joseph, Geological Surveyor, Department of Mines, Sydney. |
| 1930 | | Judd, William Percy, 49 Hirst-street, Arncliffe. |
| 1911 | | Julius, Sir George A., Kt., B.Sc., M.E., M.I.Mech.E., Culwulla Chambers, Castlereagh-street, Sydney. |
| 1932 | | Keeble, Arthur Thomas, B.Sc., Science Master, Sydney Grammar School; p.r. 55 Carlotta-street, Greenwich. |
| 1924 | | Kenny, Edward Joseph, Geological Surveyor, Department of Mines, Sydney; p.r. 5 Savings Bank Flats, Bondi Beach. |
| 1887 | | Kent, Harry C., M.A., F.R.I.B.A., 35 Beresford-road, Rose Bay. |
| 1919 | P 3 | Kesteven, Hereward Leighton, M.D., Ch.M., D.Sc., Bullahdelah, N.S.W. |
| 1896 | | King, Sir Kelso, K.B., Mercantile Mutual Building, 117 Pitt-street, Sydney. |
| 1923 | | Kinghorn, James Roy, Australian Museum, Sydney. |
| 1920 | | Kirchner, William John, B.Sc., "Wanawong," 27 Thornleigh-road, Beecroft. |
| 1919 | | Kirk, Robert Newby, 25 O'Connell-street. |
| 1932 | | Lane, Ralph Charles Bradley, M.A., B.Sc. <i>Melb.</i> , A.M.P. Society, 87 Pitt-street, Sydney. |
| 1924 | | Leech, Thomas David James, B.Sc. <i>Syd.</i> , "Orontes," Clarke-street, Granville. |
| 1920 | | Le Souef, Albert Sherbourne, Taronga Park, Mosman. |
| 1916 | | L'Estrange, Walter William, 7 Church-street, Ashfield. |
| 1909 | | Leverrier, Frank, B.A., B.Sc., K.C., Wentworth-road, Vaucluse. |
| 1929 | P 10 | Lions, Francis, B.Sc., Ph.D., Lecturer in Organic Chemistry in the University of Sydney; p.r. 21 Bridge-street, Epping. |
| 1906 | | Loney, Charles Augustus Luxton, M.Am.Soc.Refr.E., National Mutual Building, 350 George-street. |
| 1924 | | Love, David Horace, Beauchamp-avenue, Chatswood. |
| 1927 | P 1 | Love, William Henry, B.Sc., Ph.D., Cancer Research Department, University of Sydney. |
| 1884 | | MacCormick, Sir Alexander, K.C.M.G., M.D., C.M. <i>Edin.</i> , M.R.C.S. <i>Eng.</i> , 185 Macquarie-street. |
| 1930 | | MacKenzie, William Donald, M.I.Chem.E., A.I.C., Technical Director, Messrs. Lever Bros., Ltd., Balmain; p.r. 5 Tivoli-avenue, Rose Bay. |
| 1921 | | McDonald, Alexander Hugh Earle, Director of Agriculture, Department of Agriculture, Sydney. |
| 1919 | | McGeachie, Duncan, M.I.M.E., M.I.E. <i>Aust.</i> , M.I.M.M. <i>Aust.</i> , "Craig Royston," Toronto, Lake Macquarie. |

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| 1906 | P 2 | McIntosh, Arthur Marshall, "Moy Lodge," Hill-street, Roseville. |
| 1891 | | McKay, R. T., L.S., M.Inst.C.E., Commissioner, Sydney Harbour Trust, Circular Quay. |
| 1932 | | McKie, Rev. Ernest Norman, B.A. <i>Syd.</i> , St. Columba's Manse, Guyra, N.S.W. |
| 1927 | | McMaster, Sir Frederick Duncan, K.B., "Dalkeith," Cassilis. |
| 1916 | | McQuiggin, Harold G., M.B., Ch.M., B.Sc., Lecturer and Demonstrator in Physiology in the University of Sydney; p.r. "Berolyn," Beaufort-street, Croydon. |
| 1909 | | Madsen, John Percival Vissing, D.Sc., B.E., Professor of Electrical Engineering in the University of Sydney. |
| 1924 | | Mance, Frederick Stapleton, Under Secretary for Mines, Mines Department, Sydney; p.r. "Binbah," Lucretia-avenue, Longueville. |
| 1880 | P 1 | Manfred, Edmund C., Belmore-square, Goulburn. |
| 1920 | P 1 | Mann, Cecil William, 41 Jenkin-street, Chatswood. |
| 1914 | | Martin, A. H., Technical College, Sydney. |
| 1933 | P 1 | Martin, Lyster Waverley Ormsby, B.Sc., 13 Carlos-road, Artarmon. |
| 1929 | P 1 | Matheson, Alexander James, Teacher, The High School, Dubbo. |
| 1926 | | Mathews, Hamilton Bartlett, B.A. <i>Syd.</i> , Surveyor-General of N.S.W., Department of Lands, Sydney. |
| 1933 | | Mears, Arthur Cyril Weeks, A.S.A.S.M. (Electrical and Mechanical Engineering), Engineer Commander, Royal Australian Navy, Residence "F," Garden Island, Sydney. |
| 1912 | | Meldrum, Henry John B.A., B.Sc., "Craig Roy," Sydney-road, Manly. |
| 1929 | P 4 | Mellor, David Paver, M.Sc., Assistant Lecturer in Inorganic Chemistry in the University of Sydney; p.r. Flat 8, "Deanville," Milson-road, Cremorne. |
| 1928 | | Micheli, Louis Ivan, Ph.D., Colonial Sugar Refining Co., Pyrmont. |
| 1926 | | Mitchell, Ernest Marklow, 106 Harrow-road, Rockdale. |
| 1879 | | Moore, Frederick H., Union Club, Sydney. |
| 1931 | P 1 | Moppett, Warnford, M.D., Ch.M., Cancer Research Department, University of Sydney. |
| 1922 | P 20 | Morrison, Frank Richard, A.A.C.I., F.C.S., Assistant Chemist, Technological Museum, Sydney; p.r. Brae-street, Waverley. |
| 1924 | | Morrison, Malcolm, Department of Mines, Sydney. |
| 1879 | | Mullins, John Lane, M.L.C., M.A. <i>Syd.</i> , "Mount Stewart," Edgecliff-road, Edgecliff. |
| 1932 | | Munch-Petersen, Erik, M.Sc., Ph.B., Analytical Chemist, 31 Lytton-street, North Sydney. |
| 1915 | | Murphy, R. K., Dr.Eng., Chem.Eng., Lecturer in Chemistry, Technical College, Sydney. |
| 1923 | P 2 | Murray, Jack Keith, B.A., B.Sc.Agr., Principal, Queensland Agricultural College, Gatton, Queensland. |

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| 1893 | P 4 | Nangle, James, O.B.E., F.R.A.S., Superintendent of Technical Education, The Technical College, Sydney ; Government Astronomer, The Observatory, Sydney. (President, 1920.) |
| 1930 | P 1 | Naylor, George Francis King, "Kingsleigh," Ingleburn, N.S.W. |
| 1932 | | Newman, Ivor Vickery, M.Sc., Ph.D., F.R.M.S., F.L.S., "Tip Tree," Kingsland-road, Strathfield. |
| 1924 | | Nickoll, Harvey, L.R.C.P., L.R.C.S., Barham, <i>viâ</i> Mudgee, N.S.W. |
| 1891 | | † Noble, Edward George, L.S., 8 Louisa-road, Balmain. |
| 1920 | P 2 | Noble, Robert Jackson, M.Sc., B.Sc.Agr., Ph.D., Biologist, Dept. of Agriculture, Box 36A, G.P.O., Sydney ; p.r. "Warrah," 51 Boundary-street, Roseville (Hon. Secretary.) |
| 1903 | | † Old, Richard, "Waverton," Bay-road, North Sydney. |
| 1921 | | Olding, George Henry, "Werriwee," Wright's-road, Drummoyne. |
| 1930 | | O'Leary, William, S.J., Seismologist, St. Ignatius' College, Riverview, Sydney. |
| 1913 | | Ollé, A. D., F.C.S., A.A.C.I., "Kareema," Charlotte-street, Ashfield. |
| 1932 | | O'Neill, John Patrick, S.F.A.I., Chief Timber Inspector, Department of Transport, N.S.W., Transport Office, Bridge-street, Sydney ; p.r. 38 Wilberforce-avenue, Rose Bay. |
| 1928 | | Osborn, Theodore George Bentley, D.Sc., F.L.S., Professor of Botany in the University of Sydney. |
| 1921 | P 3 | Osborne, George Davenport, D.Sc., Lecturer and Demonstrator in Geology in the University of Sydney. |
| 1921 | P 1 | Parkes, Varney, Conjola, South Coast. |
| 1928 | | Parsons, Stanley William Enos, Analyst and Inspector, N.S.W. Explosive Department ; p.r. Shepherd-road, Artarmon. |
| 1920 | P 63 | Penfold, Arthur Ramon, F.C.S., F.A.C.I., Curator and Economic Chemist, Technological Museum, Harris-street, Ultimo. |
| 1933 | | Penman, Arthur Percy, B.E. <i>Syd.</i> , Mining Engineer, 10 Water-street, Wahroonga. |
| 1881 | | Poate, Frederick, F.R.A.S., L.S., "Clanfield," 50 Penkivil-street, Bondi. |
| 1919 | | Poate, Hugh Raymond Guy, M.B., Ch.M. <i>Syd.</i> , F.R.C.S. <i>Eng.</i> , L.R.C.P. <i>Lond.</i> , 225 Macquarie-street. |
| 1896 | | Pope, Roland James, B.A. <i>Syd.</i> , M.D., Ch.M., F.R.C.S. <i>Edin.</i> , 185 Macquarie-street. |
| 1921 | P 2 | Powell, Charles Wilfrid Roberts A.I.C., c/o Colonial Sugar Refining Co., O'Connell-street. |
| 1918 | | Powell, John, 17 Thurlow-street, Redfern. |
| 1927 | | Price, William Lindsay, B.E., B.Sc., 60 McIntosh-street, Gordon. |
| 1918 | | Priestley, Henry, M.D., Ch.M., B.Sc., Associate-Professor of Physiology in the University of Sydney. |

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| 1893 | | Purser, Cecil, B.A., M.B., Ch.M. <i>Syd.</i> , 185 Macquarie-street. |
| 1929 | | Pyke, Henry George, c/o Technical Research Department, Australian Gas Light Company, Mortlake; p.r. 29 Maple-avenue, Pennant Hills. |
| 1927 | | Radcliffe-Brown, Alfred Reginald, M.A. <i>Cantab.</i> , M.A. <i>Adel.</i> , F.R.A.I. <i>Cantab.</i> , c/o Department of Anthropology, University of Chicago, Chicago, Illinois, U.S.A. |
| 1922 | P 5 | Raggatt, Harold George, M.Sc., "Meru," Epping-avenue, Epping. |
| 1919 | P 3 | Ranclaud, Archibald Boscawen Boyd, B.Sc., B.E., Lecturer in Physics, Teachers' College, The University, Sydney. |
| 1931 | P 1 | Rayner, Jack Maxwell, B.Sc., A.Inst.P., Physicist to the Department of Mines, Sydney; p.r. 125 William-street, Granville. |
| 1928 | | Reidy, Eugene Nicholas, A.S.T.C., Analyst, Department of Mines, Sydney. |
| 1932 | | Richardson, Henry Elmar, Chemist, Chase-road, Turramurra. |
| 1933 | | Roberts, Richard George Crafter, Electrical Engineer, "Redcliffe," Liverpool-road, Ashfield. |
| 1928 | | Ross, Allan Clunies, B.Sc., 13 Bond-street, Sydney. (Member from 1915 to 1924.) |
| 1884 | P 1 | Ross, Chisholm, M.D. <i>Syd.</i> , M.B., Ch.M. <i>Edin.</i> , 225 Macquarie-street. |
| 1895 | | Ross, Herbert E., Govt. Savings Bank Building, 14 Castlereagh-street, Sydney. |
| 1925 | | Roughley, Theodore Cleveland, Zoologist, Technological Museum, Sydney. |
| 1929 | | Royle, Norman Dawson, M.D., Ch.M., 185 Macquarie-street, Sydney. |
| 1907 | | Ryder, Charles Dudley, D.Eng. <i>Vienna</i> , Assoc.I.R.S.M. <i>Lond.</i> , Assoc.A.C.I., F.C.S. <i>Lond.</i> , Public Analyst (by appointment), 38 Copeland-street, Beecroft. |
| 1922 | | Sandy, Harold Arthur Montague, 268 George-street. |
| 1920 | | Sawyer, Basil, B.E., "Birri Birra," The Crescent, Vacluse. |
| 1920 | | Scammell, Rupert Boswood, B.Sc. <i>Syd.</i> , "Storrington," 10 Buena Vista-avenue, Clifton Gardens. |
| 1923 | P 1 | Seddon, Herbert Robert, D.V.Sc., Director, Veterinary Research Station, Glenfield. |
| 1933 | | Selby, Esmond J., Diploma of Commerce, Sydney, Sales Manager, "Marley," Werona-avenue, Gordon. |
| 1918 | | Sevier, Harry Brown, c/o Lewis Berger and Sons (Aust.), Ltd., Cathcart House, Castlereagh-street. |
| 1924 | | Shelton, James Peel, M.Sc., B.Sc.Agr., 16 Holland-road, Bellevue Hill. |
| 1927 | | Shearsby, Alfred James, Conner-street, Yass, N.S.W. |
| 1917 | | Sibley, Samuel Edward, Mount-street, Coogee. |
| 1900 | | †Simpson, R. C., Lecturer in Electrical Engineering, Technical College, Sydney. |
| 1933 | | Slade, George Hermon, B.Sc., "Raiatea," Oyama-street, Manly. |

Elected.

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| 1922 | P 1 | Smith, Thomas Hodge, Australian Museum, Sydney. |
| 1919 | | Southee, Ethelbert Ambrook, O.B.E., M.A., B.Sc., B.Sc.Agr., Principal, Hawkesbury Agricultural College, Richmond, N.S.W. |
| 1921 | | Spencer-Watts, Arthur, "Araboonoo," Glebe-street, Randwick. |
| 1917 | | Spruson, Wilfred Joseph, S.M. Herald Building, Pitt and Hunter-streets, Sydney. |
| 1916 | | Stephen, Alfred Ernest, F.C.S., c/o Box 1158 HH, G.P.O., Sydney |
| 1921 | | Stephen, Henry Montague, B.A., LL.B., c/o Royal Sydney Golf Club, Rose Bay. |
| 1914 | | Stephens, Frederick G. N., F.R.C.S., M.B., Ch.M., Captain Piper's-road and New South Head-road, Vaucluse. |
| 1920 | P 1 | Stephens, John Gower, M.B., 135 Macquarie-street, Sydney. |
| 1913 | | Stewart, Alex. Hay, B.E., "Yunah," 22 Murray-street, Croydon. |
| 1900 | P 1 | Stewart, J. Douglas, B.V.Sc., M.R.C.V.S., Professor of Veterinary Science in the University of Sydney; p.r. "Berelle," Homebush-road, Strathfield. (President, 1927.) |
| 1909 | | Stokes, Edward Sutherland, M.B. <i>Syd.</i> , F.R.C.P. <i>Irel.</i> , Medical Officer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street. |
| 1916 | P 1 | Stone, W. G., Assistant Analyst, Department of Mines, Sydney. |
| 1918 | | Sundstrom, Carl Gustaf, c/o Federal Match Co., Park-road, Alexandria. |
| 1901 | P 15 | †Sussmilch, C. A., F.G.S., F.S.T.C., A.M.I.E. <i>Aust.</i> , Principal of the East Sydney Technical College, and Assistant Superintendent of Technical Education. (President, 1922.) (Hon. Secretary.) |
| 1919 | | †Sutherland, George Fife, A.R.C.Sc. <i>Lond.</i> , Assistant Professor in Mechanical Engineering in the University of Sydney. |
| 1920 | | Sutton, Harvey, O.B.E., M.D., D.P.H. <i>Melb.</i> , B.Sc. <i>Oxon.</i> ; p.r. "Lynton," Kent-road, Rose Bay. Professor of Preventive Medicine and Director, Commonwealth Health Dept., University of Sydney. |
| 1926 | | Tannahill, Robert William, B.Sc. <i>Syd.</i> , M.Sc., "Eastwell," 40 Cammaray-avenue, North Sydney. |
| 1915 | P 3 | Taylor, Harold B., D.Sc., Kenneth-street, Longueville. |
| 1919 | | Thorne, Harold Henry, B.A. <i>Cantab.</i> , B.Sc. <i>Syd.</i> , Lecturer in Mathematics in the University of Sydney; p.r. 96 Rutledge-street, Eastwood. |
| 1916 | | Tillyard, Robin John, M.A., D.Sc., F.R.S., F.L.S., F.E.S., Chief Commonwealth Entomologist, G.P.O. Box 109, Canberra, F.C.T. |
| 1923 | | Tindale, Harold, Works Engineer, c/o Australian Gas-Light Co., Mortlake. |

Elected.

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| 1923 | | Toppin, Richmond Douglas, A.I.C., 22 Miller-street, Hurstville. |
| 1879 | | Trebeck, P. C., Benview, Bowral, N.S.W. |
| 1932 | P 6 | Trikojus, Victor Martin, B.Sc., D.Phil., Lecturer in Inorganic Chemistry, University of Sydney, Sydney. |
| 1925 | | Tye, Cyrus Willmott Oberon, Director of Development and of the Migration Agreement Executive Committee, Public Works Dept. Building, Sydney; p.r. 19 Muston-street, Mosman. |
| 1890 | | Vicars, James, M.E., Memb. Intern. Assoc. Testing Materials, Memb. B.S. Guild., Challis House, Martin Place. |
| 1921 | | Vicars, Robert, Marrickville Woollen Mills, Marrickville. |
| 1892 | | Vickery, George B., 9th Floor, Barrack House, Barrack-street, Sydney. |
| 1933 | | Voisey, Alan Heywood, Student, The Union, University of Sydney. |
| 1903 | P 7 | Vonwiller, Oscar U., B.Sc., F.Inst.P., Professor of Physics in the University of Sydney. (Vice-President.) (President, 1930.) |
| 1910 | | Walker, Charles, "Lynwood," Terry-road, Ryde. |
| 1910 | | Walker, Harold Hutchison, Vickery's Chambers, Box 1723JJ, G.P.O., Sydney, 82 Pitt-street. |
| 1879 | | Walker, H. O., "Moora," Crown-street, Granville. |
| 1919 | P 1 | Walkom, Arthur Bache, D.Sc., Science House, Gloucester and Essex-streets. |
| 1903 | | Walsh, Fred., J.P., Consul-General for Honduras in Australia and New Zealand; For. Memb. Inst. Patent Agents, London; Patent Attorney Regd. U.S.A.; Memb. Patent Law Assoc., Washington; Regd. Patent Attorn. Comm. of Aust.; Memb. Patent Attorney Exam. Board Aust.; 4th Floor, 16 Barrack House, Barrack-street, Sydney; p.r. "Walsholme," Centennial Park, Sydney. |
| 1901 | | Walton, R. H., F.C.S., "Flinders," Martin's-avenue, Bondi. |
| 1913 | P 4 | Wardlaw, Hy. Sloane Halero, D.Sc. <i>Syd.</i> , Lecturer and Demonstrator in Physiology in the University of Sydney. |
| 1922 | | Wark, Blair Anderson, v.c., D.S.O., M.I.Q.C., c/o Thompson and Wark, T. & G. Building, Elizabeth-street; p.r. "Braeside," Zeta-street, Lane Cove, Sydney. |
| 1921 | † | Waterhouse, G. Athol, D.Sc., B.E., F.E.S., 39 Stanhope-road, Killara. |
| 1924 | | Waterhouse, Leslie Vickery, B.E. <i>Syd.</i> , 6th Floor, Wingello House, Angel Place, Sydney. |
| 1919 | | Waterhouse, Lionel Lawry, B.E. <i>Syd.</i> , Lecturer and Demonstrator in Geology in the University of Sydney. |
| 1919 | P 3 | Waterhouse, Walter L., M.C., D.Sc.Agr., D.I.C., "Hazel-mere," Chelmsford-avenue, Lindfield. |
| 1910 | | Watson, James Frederick, M.B., Ch.M., Canberra, F.C.T. |

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| 1911 | P 1 | Watt, Robert Dickie, M.A., B.Sc., Professor of Agriculture in the University of Sydney. (President, 1925.) |
| 1920 | P 34 | Welch, Marcus Baldwin, B.Sc., A.I.C., Economic Botanist, Technological Museum. |
| 1920 | P 1 | Wellish, Edward Montague, M.A., Associate-Professor in Mathematics in the University of Sydney. |
| 1933 | | Welsh, Arthur Muir, Medical Practitioner and Demonstrator in Pathology in the University of Sydney; p.r. "Sherwood," Warwilla-avenue, Wahroonga. |
| 1921 | | Wenholz, Harold, B.Sc.Agr., Director of Plant Breeding Department of Agriculture, Sydney. |
| 1881 | | † Wesley, W. H., London. |
| 1931 | | Wheatley, Frederick William, C.B.E., B.Sc. <i>Oron</i> , D.Sc. <i>Adel.</i> , A.S.A.S.M., 4 "Rhodesia," Macleay-street, Pott's Point. |
| 1922 | | Whibley, Harry Clement, c/o P.O., Fortitude Valley, Brisbane, Queensland. |
| 1909 | P 3 | † White, Charles Josiah, B.Sc., Lecturer in Chemistry, Teacher's College. |
| 1928 | | Wiesener, Frederick Abbey, M.B., Ch.M., D.O.M.S., 143 Macquarie-street, Sydney. |
| 1921 | | Willan, Thomas Lindsay, B.Sc., Ipoh, Berak, Federated Malay States. |
| 1920 | | Williams, Harry, A.I.C., c/o Whiddon Bros.' Rosebery Lanolines Pty. Ltd., Arlington Mills, Botany. |
| 1891 | | Wood, Percy Moore, L.R.C.P. <i>Lond.</i> , M.R.C.S. <i>Eng.</i> , "Redcliffe," Liverpool-road, Ashfield. |
| 1906 | P 11 | Woolnough, Walter George, D.Sc., F.G.S., Department of the Interior, Canberra, F.C.T.; p.r. "Callabonna," Park-avenue, Gordon. (President, 1926.) |
| 1916 | | Wright, George, c/o Farmer & Company, Pitt-street. Box 497AA, G.P.O., Sydney. |
| 1917 | | Wright, Gilbert, Lecturer and Demonstrator in Agricultural Chemistry in the University of Sydney. |
| 1921 | | Yates, Guy Carrington, 184 Sussex-street. |

HONORARY MEMBERS.

Limited to Twenty.

Elected.

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| 1914 | | Hill, James P., D.Sc., F.R.S., Professor of Zoology, University College, London. |
| 1931 | | Lyle, Sir Thomas Ranken, K.B., C.B.E., M.A., D.Sc., F.R.S., "Lisbuoy," Irving-road, Toorak, Melbourne. |
| 1915 | | Maitland, Andrew Gibb, F.G.S., ex-Government Geologist of Western Australia, "Bon Accord," 28 Melville Terrace, South Perth, W.A. |
| 1912 | | Martin, C. J., C.M.G., D.Sc., F.R.S., Director of Animal Nutrition, C.S. and I.R., University of Adelaide. |

Elected.

| | |
|------|--|
| 1930 | Masson, Sir David Orme, K.B.E., M.A., D.Sc., LL.D., 14 William-street, South Yarra, Victoria. |
| 1928 | Smith, Grafton Elliott, M.A., M.D., F.R.S., F.R.C.P., Professor of Anatomy in the University College, London. |
| 1915 | Thomson, Sir J. J., O.M., D.Sc., F.R.S., Nobel Laureate, Master of Trinity College, Cambridge, England. |
| 1922 | Wilson, James T., M.B., Ch.M. <i>Edin.</i> , F.R.S., Professor of Anatomy in the University of Cambridge, England, 31 Grange-road, Cambridge, England. |

 OBITUARY 1933-34.
Ordinary Members.

| | |
|------|-------------------------|
| 1919 | Earp, George Frederick. |
| 1877 | Knox, Edward William. |
| 1883 | Lingen, J. T. |
| 1905 | Taylor, John Michael. |
| 1923 | Thomas, David. |

Clarke Medallist.

| | |
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| 1909 | Roth, Walter E. |
|------|-----------------|

AWARDS OF THE CLARKE MEDAL.

Established in memory of

The Revd. WILLIAM BRANWHITE CLARKE, M.A., F.R.S., F.G.S., etc.
Vice-President from 1866 to 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia. The prefix * indicates the decease of the recipient.

Awarded.

- 1878 *Professor Sir Richard Owen, K.C.B., F.R.S.
- 1879 *George Bentham, C.M.G., F.R.S.
- 1880 *Professor Thos. Huxley, F.R.S.
- 1881 *Professor F. M'Coy, F.R.S., F.G.S.
- 1882 *Professor James Dwight Dana, LL.D.
- 1883 *Baron Ferdinand von Mueller, K.C.M.G., M.D., Ph.D., F.R.S., F.L.S.
- 1884 *Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S.
- 1885 *Sir Joseph Dalton Hooker, O.M., G.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S.
- 1886 *Professor L. G. De Koninck, M.D.
- 1887 *Sir James Hector, K.C.M.G., M.D., F.R.S.
- 1888 *Rev. Julian E. Tenison-Woods, F.G.S., F.L.S.
- 1889 *Robert Lewis John Ellery, F.R.S., F.R.A.S.
- 1890 *George Bennett, M.D., F.R.C.S. *Eng.*, F.L.S., F.Z.S.
- 1891 *Captain Frederick Wollaston Hutton, F.R.S., F.G.S.
- 1892 *Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., LL.D., Sc.D., F.R.S., F.L.S.
- 1893 *Professor Ralph Tate, F.L.S., F.G.S.
- 1895 *Robert Logan Jack, LL.D., F.G.S., F.R.G.S.
- 1895 *Robert Etheridge, Jnr.
- 1896 *The Hon. Augustus Charles Gregory, C.M.G., F.R.G.S.
- 1900 *Sir John Murray, K.C.B., LL.D., Sc.D., F.R.S.
- 1901 *Edward John Eyre.
- 1902 *F. Manson Bailey, C.M.G., F.L.S.
- 1903 *Alfred William Howitt, D.Sc., F.G.S.
- 1907 Walter Howchin, F.G.S., University* of Adelaide.
- 1909 *Dr. Walter E. Roth, B.A.
- 1912 *W. H. Twelvetrees, F.G.S.
- 1914 A. Smith Woodward, LL.D., F.R.S., Keeper of Geology, British Museum (Natural History), London.
- 1915 *Professor W. A. Haswell, M.A., D.Sc., F.R.S.
- 1917 Professor Sir Edgeworth David, K.B.E., C.M.G., D.S.O., B.A., D.Sc., F.R.S., F.G.S., The University, Sydney.
- 1918 Leonard Rodway, C.M.G., Honorary Government Botanist, Hobart, Tasmania.
- 1920 *Joseph Edmund Carne, F.G.S.
- 1921 *Joseph James Fletcher, M.A., B.Sc.
- 1922 *Richard Thomas Baker, The Crescent, Cheltenham.
- 1923 *Sir W. Baldwin Spencer, K.C.M.G., M.A., D.Sc., F.R.S.
- 1924 *Joseph Henry Maiden, I.S.O., F.R.S., F.L.S., J.P.
- 1925 *Charles Hedley, F.L.S.
- 1927 Andrew Gibb Maitland, F.G.S., "Bon Accord," 28 Melville Terrace, South Perth, W.A.
- 1928 Ernest C. Andrews, B.A., F.G.S., 32 Benelong Crescent, Bellevue Hill.

Awarded.

- 1929 Ernest Willington Skeats, D.Sc., A.R.C.S., F.G.S., University of Melbourne, Carlton, Victoria.
 1930 L. Keith Ward, B.A., B.E., D.Sc., Government Geologist, Geological Survey Office, Adelaide.
 1931 Robin John Tillyard, M.A., D.Sc., F.R.S., F.L.S., F.E.S., Chief Commonwealth Entomologist, Canberra, F.C.T.
 1932 Frederick Chapman, A.L.S., F.G.S., National Museum, Melbourne.
 1933 Walter George Woolnough, D.Sc., F.G.S., Department of the Interior, Canberra, F.C.T.
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AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

Money Prize of £25.

Awarded.

- 1882 John Fraser, B.A., West Maitland, for paper entitled "The Aborigines of New South Wales."
 1882 Andrew Ross, M.D., Molong, for paper entitled "Influence of the Australian climate and pastures upon the growth of wool."

The Society's Bronze Medal and £25.

- 1884 W. E. Abbott, Wingen, for paper entitled "Water supply in the Interior of New South Wales."
 1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper entitled "The Tin deposits of New South Wales."
 1887 Jonathan Seaver, F.G.S., Sydney, for paper entitled "Origin and mode of occurrence of gold-bearing veins and of the associated Minerals."
 1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper entitled "The Anatomy and Life-history of Mollusca peculiar to Australia."
 1889 Thomas Whitelegge, F.R.M.S., Sydney, for paper entitled "List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood."
 1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper entitled "The Australian Aborigines."
 1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper entitled "The Microscopic Structure of Australian Rocks."
 1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper entitled "The effect which settlement in Australia has produced upon Indigenous Vegetation."
 1894 J. V. De Coque, Sydney, for paper entitled the "Timbers of New South Wales."
 1894 R. H. Mathews, L.S., Parramatta, for paper entitled "The Aboriginal Rock Carvings and Paintings in New South Wales."
 1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper entitled "The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*)."
 1896 Rev. J. Milne Curran, Sydney, for paper entitled "The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found."

AWARDS OF THE WALTER BURFITT PRIZE. MONEY AND MEDAL.

Money Prize of £50.

Established as the result of a generous gift to the Society by Dr. W. F. BURFITT, B.A., M.B., Ch.M., B.Sc., of Sydney. Awarded at intervals of three years to the worker in pure and applied science, resident in Australia or New Zealand, whose papers and other contributions published during the past three years are deemed of the highest scientific merit, account being taken only of investigations described for the first time, and carried out by the author mainly in these Dominions.

Awarded.

1929 Norman Dawson Royle, M.D., Ch.M., 185 Macquarie Street, Sydney.

1932 Charles Halliby Kellaway, M.C., M.D., M.S., F.R.C.P., The Walter and Eliza Hall Institute of Research in Pathology and Medicine, Melbourne.

AWARDS OF LIVERSIDGE RESEARCH LECTURESHIP.

This Lectureship was established in accordance with the terms of a bequest to the Society by the late Professor Archibald Liversidge. Awarded at intervals of two years, for the purpose of encouragement of research in Chemistry. (This JOURNAL, Vol. LXII, pp. x-xiii, 1928.)

Awarded.

1931 Harry Hey, c/o The Electrolytic Zinc Company of Australasia, Ltd., Collins Street, Melbourne.

1933 W. J. Young, D.Sc., M.Sc., University of Melbourne.

PRESIDENTIAL ADDRESS

By ASSISTANT-PROFESSOR W. R. BROWNE, D.Sc.

(With six text-figures.)

(Delivered to the Royal Society of New South Wales, May 3, 1933.)

PART I.

During the year that is past the various activities of the Society have been maintained with wonted vigour. The papers contributed to the Proceedings compare favourably both in quantity and in quality with those of previous years.

The Council, with a view to increasing the advantages offered by the Society to its members, decided to issue the Proceedings in future in two parts instead of all at once as hitherto. An arrangement has also been made whereby authors will be supplied with 100 reprints of papers instead of 50 as heretofore, whilst extra reprints may be obtained at a fixed scale of charges.

The financial condition of the Society occasioned the Council some anxiety, especially in view of the increasing number of research papers presented, but so far, as you have gathered from the Hon. Treasurer's Report and Balance Sheet, the Society has managed to keep within its income and at the same time has continued to afford facilities for the publication of the results of original research.

The Society has now settled down comfortably in its new quarters in Science House, and the advantages of a central building to house the manifold scientific organizations in the State are becoming increasingly apparent.

The unpacking of the books belonging to the library and their bestowal and arrangement on the shelves have been proceeding apace during the year, and it is a pleasure to be able to announce that the library is once more available for reference purposes. The Council appointed Prof. J. C. Earl as Hon. Librarian, and he has lost no time in taking stock of the position and making plans for the efficient administration of his charge. It is hoped that shortly a complete and up-to-date list of works in the library will be at the disposal of members.

During the year a large and representative deputation was organised by the Astronomical Association of Great Britain (N.S.W. Branch) to interview the Minister for Education regarding the proposed abolition of the Sydney Observatory. The Society was represented by Major E. H. Booth and myself.

An important happening that took place during the year was the meeting of the Australian and New Zealand Association for the Advancement of Science, which was held in Sydney during August. The financial conditions considered, the attendance of members from the other States and from New Zealand was extraordinarily good, and the meeting was very successful. Actually the total membership of 1,084 was second only to that of the Melbourne meeting of 1890. Such gatherings are of particular usefulness in a country like our own, where the centres of population are so widely scattered. Not merely do they give opportunities for discussion and for the gaining of that inspiration which comes from communing with one's fellow-workers in science, they also promote goodwill and establish friendships which often bear fruit in hearty co-operation between workers normally far

separated from each other, things which are impossible to the same degree without personal knowledge and contact.

Advantage was taken of the occasion of this gathering to hold a special meeting of this Society for the purpose of presenting the Walter Burfitt Prize and Medal which had been awarded by the Council to Dr. Charles Halliby Kelleway of the Walter and Eliza Hall Institute, Melbourne, for distinguished original researches in regard to the venom of Australian snakes.

The annual general meeting of the Australian National Research Council which immediately preceded that of the A.N.Z.A.A.S., served to some extent to stimulate the interest of local scientific men in that body. At the meeting, consideration was given to the possibility of some sort of federation of the various Royal Societies of Australia, and in connection with the same matter a conference, which had been arranged on the initiative of the Royal Society of Victoria, was held of delegates from all the Royal Societies in Australia together with the Linnean Society of N.S.W. This Society was represented by Mr. Sussmilch and myself, and the following resolution was passed unanimously:

"The delegates to this Conference are of the opinion that an amalgamation of the scientific societies represented is not desirable at present, but they recommend that some kind of loose federation be formed such as could be obtained by each society nominating a member to the executive of the Australian National Research Council."

The resolution has since been confirmed by the councils of some of the societies concerned, and I understand that the matter has been receiving the attention of the Executive of the A.N.R.C. The decision of the societies is a significant and momentous one, as it represents the

first real attempt towards that most desirable end—a co-ordination of the activities of the various scientific bodies of the Commonwealth. There are, however, many difficulties still to be overcome, and a policy of hastening slowly is probably the wise one.

As far back as 1925 a deputation from the Australian National Research Council urged on the Prime Minister the desirability of taking steps to have the Australian sector of Antarctica placed under Commonwealth control. Largely as the outcome of its representations, an Order-in-Council was issued by the British Government early in the present year affirming that His Majesty the King had sovereign rights over the Antarctic Territory other than Adelie Land south of 60° S., between 160° and 45° E., and placing such territories under the authority of the Commonwealth of Australia from the date on which the necessary legislation should be passed by the Commonwealth Parliament. Thus an area of about one million square miles has been added to the lands under Commonwealth control. The coastline of the greater portion of this sector of Antarctica was explored by Sir Douglas Mawson during the seasons 1929-30 and 1930-31.

For more than a year the scientific workers in this country, in common with other sections of the community, suffered considerable inconvenience through the imposition of primage duty and sales tax on books imported from overseas. As the result largely of representations to the Commonwealth Government from various interested bodies, these undesirable restrictions on the dissemination of knowledge were removed in November of last year.

The new Medical School at the University of Sydney, the building and equipment of which were made possible

by a generous grant from the Trustees of the Rockefeller Foundation, is expected to be ready for occupation in the course of a few months. This inaugurates a new era in the history of medical research in this State, which is a direct result of the munificent benefaction of Mr. G. H. Bosch to medical research, made available in 1928.

The future of the study of anthropology in Australia has been causing some concern to all interested in what to the Commonwealth is a most vitally important branch of science. Some of the States have found it difficult to continue their subsidies to the school of anthropology founded some years ago in our University, but the Commonwealth Government has guaranteed a grant of £1,250 *per annum* for five years, so that continuity is being preserved for the present at least. Rev. A. P. Elkin, M.A., Ph.D., has been appointed lecturer in charge of the Department of Anthropology.

An event of more than usual interest, not only to Australia but to the scientific world at large, was the publication by the C.S.I.R. early in 1932 of a new Geological Map of the Commonwealth, with Explanatory Notes, by Sir Edgeworth David; the map, including sections, and the notes together form a very satisfying and much needed compendium of the Geology of Australia, and have been hailed with appreciation not only within the borders of the Commonwealth, but in geological circles throughout the world.

During the year there has been but slight change in the total number of our members. There have been nine resignations, but as against this eleven new members have been added to the roll. I would urge on members the importance of their endeavouring to increase the membership of the Society, and in this connection it is

pertinent to remind you that under the amended rules the subscription for members under the age of 28 years is one guinea.

It is with regret that I have to announce the loss to the Society by death of two Honorary Members, Sir Alex. B. W. Kennedy, Emeritus Professor of Engineering in University College, London, and Sir Richard Threlfall; and of four ordinary members, E. Le Gay Brereton, Sir Joseph Carruthers, G. F. Earp and J. M. Taylor.

SIR RICHARD THRELFALL, G.B.E., F.R.S., the distinguished physicist and chemical engineer, died on 10th July, 1932, in his 71st year. After a brilliant career at the University of Cambridge, and some research at the Cavendish Laboratory, he was in 1886 appointed to the Professorship of Physics in the University of Sydney, a position which he occupied for 13 years. He at once threw himself with characteristic energy into the organisation of teaching and research in physics, which under his guiding hand attained a high standard. He established traditions in his department that have left their mark till the present day, traditions of going to endless pains to develop methods of maximum possible exactness, and of overcoming obstacles at whatever cost of time or energy.

His own researches were conducted in a number of branches of physical science, and among other things had reference to the electrical properties of pure non-metallic substances, such as sulphur, selenium and nitrogen. In this work he displayed rare skill as an experimenter and much ingenuity in the designing of necessary apparatus. A galvanometer designed and con-

structed by him was more sensitive than any made up to that time. The gravity balance, made by him in conjunction with with Mr. (afterwards Professor) Pollock, was another noteworthy achievement; work in connection with this formed the subject of his last published paper in 1932.

Returning to England in 1899, Threlfall joined a well-known firm of chemical manufacturers, and devoted himself to various problems in electro-chemistry. But it was during the Great War that his ability, energy and enthusiasm found their fullest scope, and it is perhaps for his war-work that he will be chiefly remembered, especially in connection with the use of phosphorus in smoke-screens and in tracer bullets, and the use of helium gas in airships.

For his services he was knighted in 1917, and ten years later he received the honour of G.B.E. He had been elected a Fellow of the Royal Society in 1899.

Apart from his scientific attainments, Sir Richard Threlfall is still remembered in Sydney for his forceful personality, genial good humour and abounding physical energy. He joined this Society on his arrival in Sydney, and continued as a member until after his departure, contributing five papers to the Proceedings, and occupying the presidential chair in 1894. In 1921 he was elected an Honorary Member.

With his passing the world lost one who was, intellectually as physically, a giant among men.

ERNEST LE GAY BRERETON, who died on 4th August, 1932, in his 64th year, followed in his earlier years the profession of a mining engineer, but since 1908 had been lecturer and demonstrator in Chemistry in the University of Sydney. Many who have attained distinction in

the chemical world owe their early training on the practical side to his tuition. He was one of the founders of the Australian Chemical Institute, and an active member of its governing body. He became a member of this Society in 1923.

The name of SIR JOSEPH HECTOR CARRUTHERS is writ large in the history of the political and economic development of this State, in which he was an important figure for 45 years. After a legal training, he entered politics at an early age, and held with distinction various cabinet portfolios, including those of Education, Lands and the Treasury. He attained the rank of Premier in 1904, and four years later was appointed to the Legislative Council, being created K.C.M.G. shortly afterwards.

A man of many interests and of wide vision, he served his day and generation well. On the convention which framed the Commonwealth Constitution he was one of the New South Wales delegates, and later he acted on many public trusts and boards. As Minister of Education he was responsible for the establishment of the present system of technical education in the State. But he will perhaps be best remembered for his services in the cause of agriculture, in which he took a great interest, and on which he was an expert authority, well equipped with both theoretical and practical knowledge. The very valuable report prepared by the Select Committee on "The Conditions and Prospects of the Agricultural Industry" in 1921 was largely due to his initiative and energy as chairman.

He took an active part in public affairs almost up to the time of his death on 10th December, 1932, in his 75th year. His membership of this Society commenced in 1920.

GEORGE FREDERICK EARP, who died on 12th March, 1933, aged 75 years, came to this country from England in 1883, and engaged in commercial pursuits, the firm which he founded being among the pioneers of the South Maitland coalfield. He was appointed a member of the Legislative Council in 1900. During the Great War he interested himself particularly in the Polish Relief Fund, and as a reward for his services was made the first Consul-General in Australia for the Polish Republic. Mr. Earp joined this Society in 1919.

JOHN MICHAEL TAYLOR, who died on 18th April, 1933, at the age of 72, became a member of this Society in 1905. He was for many years in the teaching-service of the State, until his appointment as a member of the Public Service Board; later he practised as a solicitor. He was the author of an informative "Geography of New South Wales", which was used extensively as a school textbook.

I have also to announce with regret the death of DR. WALTER E. ROTH, of British Guiana, who was awarded the Clarke Memorial Medal in 1909 for his ethnographical researches among the North Queensland aborigines.

PART II.

AN ACCOUNT OF POST-PALÆOZOIC IGNEOUS ACTIVITY IN NEW SOUTH WALES.

INTRODUCTION AND ACKNOWLEDGMENTS.

A few years ago, in a Presidential Address to the Linnean Society of New South Wales⁽¹⁾ I attempted to outline the history of igneous activity in this State down to the close of the Palæozoic Era. That some of the views expressed in that address have since been proved erroneous is a matter for gratification, since it shows

that in the meantime investigation in the domain of geological science has not been at a standstill. This evening I propose to resume the tale at the point where it was broken off in 1928, and to place before you a summary account of our knowledge of igneous action in New South Wales since the close of Palæozoic time. Before proceeding to do so, however, I should like to make grateful acknowledgment of my very great indebtedness to many colleagues, both within and without the State Geological Survey and the Geology Department of the University of Sydney. Help has been freely given, and unpublished information freely imparted in the true spirit of scientific co-operation. I would specially mention the splendid assistance rendered by Miss G. A. Joplin, B.Sc. Outside the State I have received valuable help from Prof. Richards and Dr. Bryan of the University of Queensland, and from Mr. D. J. Mahony, M.Sc., Curator of the National Museum, Melbourne. Indeed this address is to be regarded in some degree as the result rather of a pooling of knowledge on the part of many workers than of the effort of one. At the same time I must take personal responsibility for any errors and omissions, and for anything in the way of deduction or speculation. Full advantage has been taken of many published papers and reports, and I have found of particular usefulness the Geological Survey Reports on the Western and Southern Coalfields, with their very careful and detailed field and laboratory observations of the Tertiary rocks.

MESOZOIC:

Tectonics, etc.

It would appear that the last horizontal forces of any considerable magnitude which affected this State were

those which at the close of Permian time folded the Kuttung and Kamilaroi strata in the eastern part, and were associated with the injection of the New England granites. During Mesozoic time the crustal movements were in a general vertical direction, with some tilting in places. Probably at the close of the Cretaceous folding movements affected south-eastern Queensland,⁽²⁾ but they were not experienced in New South Wales, except possibly in the extreme north-east.

The only signs of vulcanicity of Mesozoic age have been found among the sediments, but except for the Narrabeen Series there has been little microscopical examination of the strata for pyroclastic material. There is much evidence of explosive activity amid the Kamilaroi strata, and quite conceivably similar conditions prevailed during the accumulation of the Mesozoic freshwater and marine deposits.

Quite possibly, too, there were subaerial as well as subaqueous extrusions, but if so these must all have been swept away during the severe peneplanation which occurred at the close of Cretaceous time.

Triassic.

Strata of this age in New South Wales are confined to the predominantly freshwater series typically developed about Sydney. It has been customary to regard Triassic time in this State as having been almost free from volcanic activity, but while there is an absence of contemporaneous lavas, there are evidences of explosive activity during the deposition of the beds of the Narrabeen Series. Sir Edgeworth David⁽³⁾ many years ago proved the existence of a horizon of cupriferous tuffs low down in the series, consisting chiefly of rounded and sub-

angular fragments of trachyte and other volcanic rocks, with chips of felspar and other minerals. Near the top of the series are beds of fine cupriferous chocolate shale, interbedded with more coarsely-grained greenish-grey rocks, which, though much decomposed, have the appearance of tuffs. The chocolate shales have themselves been regarded as basic tuffs, with much admixture of sedimentary material. It is difficult to assign a reason for their colour as compared with that of the associated greenish tuffs; possibly the material was extruded on to the land and oxidised before being washed into the Triassic Narrabeen Lake.

A microscopical examination of specimens from the Balmain Colliery Shaft makes it clear that the sandstones forming the major part of the Narrabeen Series at Sydney contain, in addition to the dominant quartz, a fair amount of felspar, both orthoclase and plagioclase, as well as occasional chips of fresh trachyte and porphyritic felsite. Similar features are found in strata from the Illawarra coast and from north of Narrabeen. In view of the fact that the Narrabeen beds to the west of the Blue Mountains, that is, near the source of the granitic material forming them, are mostly siliceous sandstones, it would seem that unless there was another nearby source of supply east of the present coast-line the coastal rocks are really tuffaceous. This gives point to the suggestion that the volcanoes responsible for the eruptions were situated not far east of the present coast, and it would appear that explosive activity was pretty continuous during the Narrabeen epoch.

The chocolate shales are very widespread, outcropping at Narrabeen and farther north, on the Illawarra coast, in the Burraborang Valley, and the western valleys of

the Blue Mountains, beyond Rylstone, and at Pokolbin and elsewhere in the Hunter and Goulburn Valleys.

Everywhere the sedimentary character of the rocks is dominant, and in the Illawarra and Blue Mountain districts pyrites casts are common.

Volcanic activity virtually ceased with the end of Narrabeen time. The Hawkesbury Series has not had detailed microscopic investigation, but its field-characters are dominantly those of a rather siliceous sandstone, without foreign admixture. In the succeeding Wianamatta epoch there was apparently little volcanic activity, but occasional hard calcareous bands occur in the Wianamatta shales which have a tuffaceous aspect, and on some horizons in the Upper Wianamatta (ostracod sandstone) Stage volcanic ash is admixed with other sediments. Contemporaneous volcanic activity in the Trias, therefore, was not great, and was confined, so far as is known, to explosive eruptions.

Jurassic.

During this period there was deposition of sediment in the large freshwater Walloon Lake, principally in Queensland, but extending south to Dubbo in New South Wales. A few years ago E. J. Kenny,⁽⁴⁾ of the Geological Survey, discovered evidences of contemporaneous vulcanism among Mesozoic beds and beneath fossiliferous Jurassic strata. Owing to the absence of fossils, it is impossible to fix definitely the age of the underlying sedimentary series. The lava-flows, forming what Kenny has called the Garrawilla Series, have a thickness of as much as 600 feet in places, and are found typically between Tambar Springs and Mullaley, east of the Warrumbungle Mountains, consisting there of somewhat altered fine-

grained olivine-basalts. At Weetaliba, near Coolah, in what is apparently the same series, nepheline-basalts occur. Between Coonabarabran and Rocky Glen the series contains an abundance of beautiful stilbite.

This is the only instance so far recorded of contemporaneous lava-flows in New South Wales belonging to Mesozoic time.

Cretaceous.

No igneous activity is known to have occurred during this period in New South Wales. Richards, Bryan and Whitehouse a few years ago discovered signs of granite intrusive into the Clarence (Jurassic) Series between Drake and Tabulam,⁽⁵⁾ and there is just a possibility that the intrusion took place during the folding that marked the close of Cretaceous time.

INTRUSIONS OF INDETERMINATE AGE.

There are in various parts of the State a number of minor intrusions, in the shape of dykes, sills and plugs, the geological ages of which cannot be fixed within narrow limits, but which are in some cases petrologically linked with each other.

The Good Dog Mountain Intrusions.

A rather peculiar series of intrusions has been described from the Illawarra district.⁽⁶⁾ They include a neck and a number of sills and dykes in the neighbourhood of Good Dog Mountain.

The largest neck-like intrusion is composed of quartz-diorite with a mineral assemblage approaching that of monzonite, except that the proportion of orthoclase is too low; this grades into pyroxenite and is intersected by

dykes of aplite. The dykes and sills are basic, partly hornblende- and mica-lamprophyres, and partly porphyrite, all with orthoclase showing. Another lamprophyre, apparently allied to the foregoing, outcrops on the Robertson tableland.

Chemically and mineralogically these rocks are very different from any of the known Tertiary intrusions, and they are perhaps most nearly allied to the Upper Kamilaroi monzonites and latites of the same district, though the resemblance is not extraordinarily close. But they are intrusive through the Narrabeen and Hawkesbury Triassic beds, and their presence may indicate that injections from the Kamilaroi monzonitic magma continued into Triassic or post-Triassic time. Nevertheless it must be remembered that the intrusion of tonalites and quartz-monzonites has formed part of the series of eruptive episodes which included the extrusion of the basaltic lavas of the Tertiary Brito-Arctic or Thulean province, and it may be that the rocks under discussion are related to the earlier Tertiary eruptions hereinafter referred to.

Rocks of the Quartz-Dolerite Kindred.

There are along the east coast and the highlands of the Main Divide scattered intrusions belonging to the quartz-dolerite kindred, some of which, at all events, are post-Palæozoic. One of the largest is that which forms Tillynambulan Mountain, near Moss Vale, a somewhat flat-topped hill, composed of exceptionally fresh ophitic olivine-dolerite with enstatite-augite and a little interstitial quartz and micropegmatite. The mass, which is perfectly uniform in texture throughout, is about 250 feet thick, and appears to be a denuded sill resting on Triassic Wianamatta shales. Unfortunately it is isolated, so that

its relation to the Tertiary newer basalts in the neighbourhood is not known.

Many years ago Mr. G. W. Card, then Curator of the Mining Museum, determined a specimen received from an unknown locality in the same neighbourhood to be a quartz-dolerite. This, though devoid of olivine and somewhat coarser in grainsize, is clearly a close relation of the Tillynambulan rock. It has good micropegmatite, and the dark minerals include salite and a little hypersthene.

A pipe and a series of dykes of quartz-dolerite were described by L. A. Cotton⁽⁷⁾ from Oakey Creek and Staggy Creek, in the Inverell district, cutting through some of the New England late-Permian granites, but covered by Tertiary basalt, probably belonging to the older series. These rocks are rather decomposed, and contain a good deal of interstitial chlorite as well as some quartz, though no micropegmatite is present. Chemically they are not unlike some of the typical quartz-dolerites. The Oakey Creek rock achieved a certain degree of fame through the discovery of a diamond *in situ* in it many years ago.

A dyke of dolerite was recorded by Woolnough⁽⁸⁾ from the Shoalhaven Valley at Tallong, which proves to be ophitic, devoid of olivine and somewhat chloritised, and to contain a pyroxene with small optic axial angle, probably enstatite-augite. Recently several more similar dykes were discovered by Mr. D. Garretty along the course of the Lower Shoalhaven and up the river as far as Nerriga; many of these contain enstatite-augite, while some exhibit interstitial quartz. Woolnough was of the opinion that the Tallong dyke could be traced up through the Upper Kamilaroi strata at Badgery's Lookdown, but it does not appear to cut through the somewhat alkaline Tertiary

basalt flows on top, so its epoch of intrusion may be somewhere between the end of the Palæozoic and the time of eruption of the Tertiary newer basalts.

All the three series of intrusions just described are post-Palæozoic, and one of them is Triassic or post-Triassic, while all are at the latest early or middle Tertiary. But there are a number of other occurrences whose ages are not fixed even between these wide limits. A large intrusion of quartz-dolerite transgressive through Silurian strata has been reported by Mr. C. W. Morris, B.E., from the Goulburn district, which shows the characteristic bending and distortion of the pyroxenes, and Dr. Ida A. Brown has shown me slides of dolerite from the Brogo district, on the South Coast, and from the Araluen-Braidwood road, which are very close in general characters to those of the Shoalhaven described above, but without quartz. A very similar rock was found somewhere not far from the Queensland border at the head of the Clarence River. Woolnough⁽⁹⁾ has described a dolerite dyke cutting through the granite of the Kosciusko Plateau, whose augite, he specially notes, has a very small optic axial angle. I have observed quartz-dolerites, with interstitial micropegmatite and much biotite, forming small necks and dykes through Silurian and Ordovician strata and granite at Bredbo, 20 miles north of Cooma.

It would be folly to suggest an age-correlation of all these very scattered occurrences on the score of petrological similarities. As a matter of fact, though they would all be grouped with the quartz-dolerite kindred, there are differences between them in texture, degree of alteration and other things. Nevertheless some ground exists for the surmise that there may have been during Mesozoic and Tertiary time one or more epochs of

intrusion of rocks of this type in eastern New South Wales. The rock of the Tillynambulan sill is quite comparable with the Tertiary basalts in freshness, and in its physiographic relations one is tempted to compare it with some of the Tertiary basic intrusives elsewhere on the tablelands.

TERTIARY.

We now pass on to consider the very important and widespread volcanic activity which affected a broad strip, not merely of New South Wales, but of eastern Australia and Tasmania, during Tertiary time. Much has been written on the extrusive rocks of this era by Queensland, New South Wales and Victorian geologists, and there has been much doubt and uncertainty in regard to the chronology of various outbursts. To envisage and investigate all the problems concerned would require many years of research, and in this address it is possible to do little more than bring together and co-ordinate some of the results of other workers, and perhaps to suggest some lines along which future research may be directed.

Classification and Chronology.

The conception of an older and a newer series of Tertiary basalts appears to have originated in Victoria, and was perhaps first applied by C. S. Wilkinson in New South Wales to some of the New England flows. Later, a series of alkaline lavas, chiefly of intermediate type, was recognised, and these were eventually by some workers placed between the older and newer basic series, though originally they had been thought to antedate the older flows. Palæontological criteria for the separation of older and newer basalts were always unsatisfactory, and Suss-

milch,⁽¹⁰⁾ in 1923, attempted a chronological classification based partly on physiographic criteria. The older basic series (called "monadnock basalts") were taken to be those occurring as physiographic residuals, which presumably had been for longer exposed to denudation than the newer or "plateau" basalts, which still cover large continuous areas. In this classification the leucite-basalts, as well as some normal basalts, were grouped with the alkaline series, which was placed chronologically after the "plateau" basalts.

It would appear that the physiographic criteria of relative age, while in a general way reliable, may in fact break down, since the degree of erosion is a function, not merely of length of time, but also of elevation, distance from the sea, original extent and thickness of the flow, and other factors. For example, the basalt residuals of the Blue Mountain plateau, which are placed by Sussmilch in the older or "monadnock" group, are perhaps more naturally explained as remnants of relatively small flows of the newer series, and the Bald Hills flow at Bathurst is clearly portion of a "plateau" flow which formerly extended to Mt. Apsley and Mt. Pleasant, and which was dissected by the Macquarie River in late-Tertiary or post-Tertiary time. Further, some of the "monadnocks" are almost certainly remnants, not of flows at all, but of sills, like Mt. Bocobel* in the Cudgegong district, Mt. Dangar, near Merriwa, Nullo Mountain in the Blue Mountain area, and Billyrambija, near Marulan.

The use of the term "plateau-basalt" is inadvisable, since, though it was used by Geikie and others in the sense in which Sussmilch employs it, of late years it has,

* Mr. L. L. Waterhouse has kindly drawn my attention to this occurrence.

rather unhappily but none the less definitely, been given a petrological significance as well.

As will be shown later, there is reason to believe that the so-called alkaline lavas and intrusions antedated the newer basalts.

For present purposes the Tertiary igneous rocks may be grouped as follows:

(1) Flows:

- (a) The older basic series;
- (b) The middle series, distinctly alkaline for the most part;
- (c) The newer basic series, including nepheline- and leucite-basalts, and some intercalated acid lavas.

(2) Intrusions:

- (a) The older basic intrusives;
- (b) The middle series of alkaline syenites, tinguaïtes, *etc.*;
- (c) The basic volcanic necks;
- (d) The newer basic intrusives;
- (e) The coastal basic dykes and minor sills.

This is largely a grouping of convenience, and further study will probably suggest modifications or corrections. The sequence in each of the two subdivisions is intended to be largely chronological. It is considered not improbable that the flows and intrusions of the middle series were connected, and that they were more or less synchronous. The series of older basic intrusives was probably connected with the older basic flows, the basic necks were undoubtedly feeders to some of the newer basic

flows, and the newer basic intrusives followed closely on them. The time-position of the coastal dykes and minor sills is by no means certain.

A group of older basalts is retained largely because of the fact that such authorities as Wilkinson, David and Andrews, with much personal experience in the field, have recognised their existence in New England and elsewhere. That flows of Tertiary basalt were poured out at epochs separated by a considerable interval is proved by a number of observations. David⁽¹¹⁾ records that at Vegetable Creek (Emmaville) an older basalt flow partially filling a valley suffered erosion, and then had as much as 100 feet of sediment deposited on top of it before the effusion of a later flow. Andrews⁽¹²⁾ found at Kiandra two distinct basalt-covered deep leads, the Kiandra lead and the Round Mountain lead. These are not many miles apart, but the latter is about 700 feet below the level of the former. A somewhat similar state of affairs is to be observed to the east of Cooma, where a basalt flow overlying water-bearing sand and gravels caps a ridge at an elevation of 500 feet above another series of basalt-capped

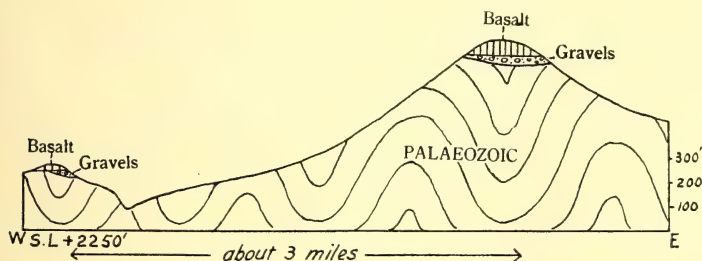


Fig. 1.—Sketch Section east of Cooma showing older and newer basalt.

gravels some three miles to the west (Fig. 1). Here we are dealing with flows so far separated in time that considerable erosion was accomplished between the epochs of

eruption. All these examples—and doubtless they could be added to—are certainly suggestive of an older and a newer series of flows, but the evidence does not enable us to say that the time-interval is as long as that between, say, the Victorian older and newer basalts.

It would appear that the older Inverell and Emmaville lavas were in the first instance correlated by Wilkinson with the older basalts of Victoria partly on the association with them of lateritic cappings. Certainly the occurrence of such laterites, both massive and pisolitic, separating the older and younger of these New England flows, would imply a very long interval of time, but the presence of a lateritic cover can hardly in itself be recognised as a valid criterion for correlation, since very similar cappings are found at Wingello and elsewhere on the Southern Plateau, overlying what are regarded as newer basalts, and in places separated from them by layers of ferruginous sandstone.

A matter that has an important though indirect bearing on the question of an older series of basic flows is the existence of two distinct series of basic intrusives, as described later. These intrusives must, on chemical and mineralogical grounds, be regarded as co-magmatic, yet one series, closely associated with and clearly related to the newer basalts, is very much younger than the other.

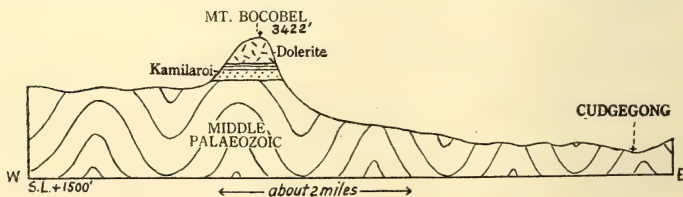


Fig. 2.—Sketch Section showing the denuded sill of Mt. Bocobel in its relation to the physiography. (After L. L. Waterhouse.)

These older intrusives must surely have been likewise the sequelæ to an older series of flows. The denuded sills, too, such as Mt. Bocobel (Fig. 2) and Mt. Dangar, which rise to heights measured by hundreds of feet above the plateau-levels on which the later basalts were poured, are clearly relics of a series of intrusions which were emplaced long before the peneplain level was eroded on which the later basalts were poured. The presence of sapphires⁽¹³⁾ in the leads underlying the newer basalts also points to an earlier series of basalts from which the alluvial stones were derived.

Taking all the evidence, indecisive as it is in any specific instance, one is driven toward the conclusion that we have in this State representatives of an older as well as of a newer series of basalt-flows, and that, as shown later, the former, in some instances at all events, preceded the rocks of the middle series, while the latter followed them.

A question of some importance arises in regard to the time-position of what I have called the middle series, chiefly of alkaline intermediate rocks, relatively to the newer basalts. David and Woolnough⁽¹⁴⁾ have contended that they antedated the newer basalts, whereas Sussmilch, chiefly on physiographic grounds, holds the converse view. I have lately had some little opportunity of examining this question in the field, and have come to some rather definite conclusions. The alkaline rocks comprise laccoliths and sills and dykes of syenite, tinguaitite, *etc.*, and plugs and flows of trachyte and rhyolite, and a number of lines of evidence, summarised below, suggest that these are co-magmatic. In one instance, that of the Warrumbungle Mountains, the age of the eruptions is proved to

be Tertiary by the presence under them of leaf-beds, and many of the other occurrences are known to be post-Triassic or post-Jurassic. The evidences obtained as to age relative to the newer basalts are as follow:

(a) In the Barigan-Rylstone district laccoliths of tinguaita and other rocks have been dissected by stream-action, and now rise from broad mature valleys. This dissection was evidently well advanced in pre-newer basalt time, for at Ulan and Bylong and near Barigan we find remnants of basalt-flows which sometimes occupy the floors and in other cases have flowed over the walls on to the floors of these valleys and others of the same system.

(b) In the Canoblas area near Orange there is an alkaline volcanic centre which has been well described by Sussmilch and Jensen.⁽¹⁵⁾ Around the flanks of this centre are extensive flows of the ordinary newer basalt. In their original paper, Sussmilch and Jensen considered this newer basalt, which is always at a relatively low level, to have lapped round the base of the old alkaline volcano and filled up valleys in its lava, but Sussmilch later⁽¹⁰⁾ interpreted the evidence differently, and considered the alkaline series to have been poured out on a platform of newer basalt. An examination chiefly of the country about Spring Creek, on the Cargo Road, shows pretty conclusively that the original interpretation by Sussmilch and Jensen is the correct one. It is quite evident that the newer basalt there is filling what was a fairly broad valley cut in the trachyte.

(c) In the Mittagong-Bowral district there is an interesting series of intrusions. In particular, Mt. Gibraltar is a denuded laccolith of microsyenite whose intrusion has tilted the Hawkesbury sandstone to north, east and

south; newer basalt has flowed over the eroded edges, and even over the syenite (Fig. 3), as recorded by Taylor and Mawson.⁽¹⁶⁾ A few miles to the east of Mt. Gibraltar a mass of sölvbergite intrusive through Hawkesbury sandstone has been laid bare by erosion, and is now partially covered and partially surrounded by newer basalt.

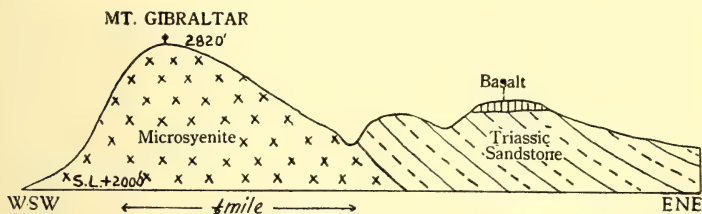


Fig. 3.—Sketch Section showing the relation between syenite and newer basalt at Bowral.

These occurrences prove beyond all doubt that the rocks of the middle series had been erupted and subjected to prolonged erosion and dissection prior to the effusion of the newer basalts.

As regards the question of an older and a newer series of basic intrusives, Jensen⁽¹⁷⁾ produces clear evidence that in the Nandewar Mountains there are laccoliths of alkaline dolerite older than the trachytes belonging to the middle series. He likewise describes similar dolerites from Ipswich in Queensland,⁽¹⁸⁾ which antedate the trachytes; these dolerites are considered by Dr. W. H. Bryan to belong to an early Tertiary basic series.

I have had an opportunity of examining the relations between the essexite and trachyte at Mt. Jellore, near Mittagong, described by Taylor and Mawson. The former occurs as a sill through Triassic strata, the latter as a plug in close contiguity to the essexite. Taylor and Mawson

express the opinion, but without giving any very definite evidence, that the essexite is the younger rock. My conclusion in regard to the matter agrees with Jensen's, that the trachyte is intrusive through the basic rock. In certain places the strata dip to the east in harmony with and under the essexite sill, but at one point on the flank of the trachyte plug, and practically in contact therewith, they have a dip of 32° in a direction W. 36° S., an effect which Taylor and Mawson have ascribed to the essexite intrusion. The direction of the dip, however, appears to me to relate the disturbance directly to the plug, and it would therefore seem to have been superimposed on that associated with the essexite intrusion. This tilting of the strata around the trachyte plug recalls the similar but more pronounced tilting associated with the trachyte plugs in the Warrumbungle Mountains, near Tambar Springs, and elsewhere.

Incidentally, Taylor and Mawson point out that the essexite has tilted the strata, whereas the basalts were poured out over their eroded edges; the former rock therefore long antedated the extrusion of the newer basic flows.

As distinct from these older intrusions, theralites and allied types of intrusion have been described by Benson⁽¹⁹⁾ and observed by myself forming sills and plugs through the newer basalts of the Liverpool and Mt. Royal Ranges, and closely allied to them in composition.

It may therefore, I think, be considered that two series of alkaline basic intrusives may be recognised, one antedating the middle series, and probably connected with an older series of basic lavas, the other postdating and closely related to the newer basalts.

Though it is generally assumed that most of the basalts came from fissure-eruptions, there are upwards of 100 volcanic necks known, for the most part confined to a few areas, and in some cases the age is proved by association with flows of newer basalt. A number of them, particularly about the Sydney district and on the Blue Mountains, contain a characteristic breccia, which serves to link them together in age. Among the fragments in the Hornsby neck Benson⁽²⁰⁾ records an essexite, a type which is not known in this State except from among the Tertiary intrusives; this suggests that the Hornsby neck and others of similar kind belong to the newer basalt period. According to Carne,⁽²¹⁾ some of the Blue Mountain necks have still preserved around their rims portions of the original lava-cones, with tuff and agglomerate. It is hard to believe that these features have been preserved from erosion since the Miocene, the period to which the older basalts are usually assigned.

Further, the basalt of some of the necks is chemically and mineralogically very closely similar to that of some of the newer basalt flows.

The basic dykes and minor sills, of which there are so many in the coastal areas, are possibly in part related to the necks, being in a few cases actually found in association with them. But by far the greater number of them have no visible connection with centres of eruption, and it is doubtful whether they do not form a separate intrusive series, magmatically related, however, to the newer basalts. There is the possibility that all the dykes, even those along the coast, may not belong to the same intrusive episode; some of them, like some far inland, may be feeders to the flows of the newer basic series, and some

may even conceivably date back to the epoch of the older basalts.

The newer basic series of flows has been determined as such (*a*) on the evidence of the fossil plants in the associated deep leads; (*b*) by their field-relations with the rocks of the middle series and of the older basic series; (*c*) by physiographic considerations.

The extensive areas of basalt, often retaining the flat surface representing approximately the original upper surface of the latest flow, are referred to the newer basic series, though in other cases where the flows have been thin and erosion strong, these newer flows may be represented only by isolated cappings and residual patches, like those of Mts. Hay, Tomah, Irvine, *etc.*, in the Blue Mountains.

The nepheline-bearing basic lavas are included with the newer basic series on account of close field-association and on petrological grounds, all gradations being observed from olivine-basalts through basanites to true nepheline-basalts. Some of the nepheline-basalts form neck-fillings. The leucite-basalts at Byrock,⁽²²⁾ Lake Cudgellico⁽²³⁾ and Griffith* are in such isolated positions (Fig. 5) that not even their Tertiary age can be certified. At Harden,⁽²⁴⁾ however, they are brought into close geographical relation with nepheline-basalt or monchiquite, and in addition they nearly all contain some nepheline and are in other respects similar to the nepheline-basalts, so that they can reasonably be regarded as members of the newer basic series. Some of the leucite-basalts may be neck-fillings.

* Discovered a few years ago by Mr. L. L. Waterhouse.

It should be borne in mind that, while the rocks of the middle series may all have been contemporaneous, or nearly so, the eruption of the newer basic series may have been spread over a considerable time, and the same may be true of the older basic series.

Geological Time-Range of the Eruptions.

This question cannot be considered without reference to the Tertiary igneous rocks of Victoria and Queensland. In the former State there are quite definite indications⁽²⁵⁾ that the earliest basic lavas were poured out over river-gravels on land which was subsequently submerged. At Torquay, Royal Park (Melbourne), Flinders and elsewhere, Janjukian (Miocene) limestone and other marine strata rest on the weathered surfaces of the flows. At Mornington a bore passed through Balcombian (Oligocene or Lower Miocene) marine strata into basalt overlain by a lignitic series. Others of the older basalts appear to be interbedded with the Janjukian and even to overlie it. There is therefore palæontological evidence that the rocks grouped as the older basalts represent a series of flows ranging in time over both the Oligocene and the Miocene periods.

The presence of the fossil plant *Cinnamomum polymorphoides* was noted in freshwater beds underlying the older basalt in South Gippsland, and on the evidence of this plant, on physiographic grounds and on the state of weathering of the rocks, several areas of basalt in eastern Victoria have been classed as older basalts.

For the Victorian newer basalts the upper (earlier) time-limit is not so accurately fixed. They follow the trachytic series at Mt. Macedon,⁽²⁶⁾ and elsewhere overlie deep leads whose fossil-contents are believed to be younger

than those of the leads underlying the older basalts. At Melbourne and elsewhere the newer basalts lie upon the eroded surfaces of the older series. There is evidence in the Camperdown district that the latest of the newer basalts may have poured out from central vents along with volcanic ash and other fragmental material in Pleistocene or even Recent time.⁽²⁷⁾

For the south-east of Queensland, Richards⁽²⁸⁾ regarded the Tertiary volcanic rocks as divisible into an older and a newer basic group, with a middle series largely alkaline. Since Richards' paper was written, further work has shown that this simple division cannot be strictly maintained. I have recently been informed that at Red-bank Plains, Cooper's Plains and elsewhere in the region the lowermost basalts are interbedded with freshwater sediments which on fossil evidence may be at least as old as Oligocene. Some of these basalts have been proved to a depth of 900 feet below present sea-level at Bundamba. Apparently there are also basalts later than these but antecedent to the trachytic eruptions, and then there are newer or post-trachyte basalts. Volcanic activity in Queensland, as in western Victoria, continued in places into Pleistocene and even Recent time.⁽²⁹⁾

Richards considers the extensive rhyolites, pitchstones and agglomerates of the Macpherson Range to be coeval with the trachytes, and to have antedated the outpouring of the newer basalts, and the distinction between older and newer basic series appears to be made by him in part according to their respective positions in regard to the trachytes or pitchstones. But on his map these latter rocks appear nowhere in contact, though in a few places they are close together, and in a recent section through the Springbrook Plateau Morton⁽³⁰⁾ shows that there are

really two series of rhyolitic pitchstones with basalt between them as well as above and below (Fig. 4). It would thus appear that the mere occurrence of rhyolite or pitchstone above or below a basalt is not sufficient

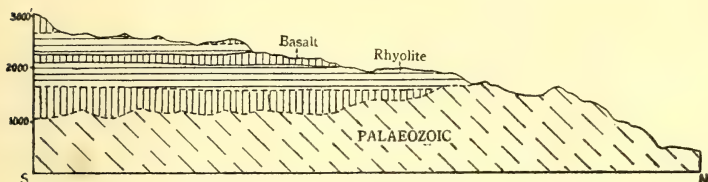


Fig. 4.—Section through the Springbrook Plateau, south-eastern Queensland. (After C. C. Morton.)

evidence that the basalt should be placed in the older or the newer basic series. Richards records dacites from two localities, which appear to be rather similar, and it is perhaps significant that in one case the dacite is later than the trachyte, while in the other it is earlier than the rhyolites. If the eruption of the rhyolites and pitchstones is to be regarded as an episode in the outpouring of the newer basic series, then all the basalts of the Springbrook and Lamington Plateaux and of Mt. Lindesay may belong to the newer series. Andrews⁽³¹⁾ mentions the existence of trachyte at low levels at Mt. Lindesay, well below the pitchstone and much of the basalt underlying it.

Incidentally, Mahony⁽³²⁾ records that a pitchstone, very similar in composition to Richards's dacite, was found among the newer basalts of Victoria.

For both Victoria and Queensland, therefore, it would seem that, if an epoch of extrusion of the trachytes coincident in both States be taken as a fixed point of reference (and this is perhaps not unreasonable), there are to be recognised a series of older basic rocks, poured out intermittently over a considerable range of time, and

a series of newer basalts whose interval of extrusion extended in places into Recent time, but whether the various members of the older series and of the newer series are exactly coeval in the two States it would be very difficult to say.

In New South Wales there are no Tertiary marine or other deposits by which an upper limit to the geological age of our basalts may be accurately determined. Certain quartzites (really Tertiary sands silicified through overlying basalt-flows now eroded away) at Dalton, near Gunning, contain *Cinnamomum polymorphoides* and *C. leichhardtii*, and on the strength of these and other forms have been correlated⁽²⁵⁾ ⁽³³⁾ with the older leads of Victoria. *C. polymorphoides* has been identified in the leads of Vegetable Creek (Emmaville) underlying the lowest basalt-flow, and *C. leichhardtii* at Newstead and Elsmore in the Inverell district.⁽³⁴⁾ It was principally on this evidence of the fossil flora that the basalts of these New England localities were correlated with the older basalts of Victoria, and referred to the Miocene period. In a number of leads fossil fruits have been found, both in Victoria and New South Wales. Since these represent entirely extinct genera, and have been found in Victoria under what are regarded on other evidence as older basalts, Walcott considers it natural to place the fruit-bearing sediments with the older leads; among these are certain of the Gulgong leads, and the basalts there would, according to him, therefore be referred tentatively to the Miocene period. On physiographic evidence, however, there can be no doubt that the Gulgong basalts belong to the newer series.

It is interesting to note that *Cinnamomum leichhardtii* has been observed in tuffs belonging to the trachytic series

of the Warrumbungle Mts.⁽³⁵⁾ While the time-range of this plant is not known, the occurrence would tend to link the lavas of the middle series more closely with the older than with the newer basic series.

The only flows of the newer basic series in this State which stand in demonstrable relationship to fossiliferous strata are on the South Coast near Moruya; Dr. Ida A. Brown has drawn my attention to them. These basalts, which in some places descend below sea-level, overlie beds of coarse grit containing fragments of pelecypods which, according to Mr. F. A. Singleton, M.Sc., of Melbourne, are to be regarded tentatively as of Upper Cainozoic age. In other parts of the State the basalts overlie plant-beds containing forms which are considered to differ but little from those of the present day.

The palæobotanical evidence appears to be regarded nowadays as of little or no value in fixing accurately the geological age of the leads, but it seems possible that it may have some usefulness for purposes of correlation, though in view of the uncertainty as to the length of the time-range of the plants even this is doubtful.

The following tentative statements may be made regarding geological ages of the N.S.W. rocks:

- (1) The middle series followed fairly closely after and was probably closely connected with the older basic series, whose extrusion may have occurred in Oligocene to Miocene time.
- (2) A long interval, during which considerable denudation and mature valley-erosion was accomplished, separated the middle series from the newer basic series.

- (3) The newer basic series, as pointed out by

Andrews,⁽³⁶⁾ or the bulk of it at any rate, was most probably poured out fairly early in the Pliocene period, since there was much post-basaltic erosion before the commencement of the Kosciusko uplift, which is usually assigned to late-Pliocene time.

- (4) There are apparently some grounds for believing, on fossil evidence,⁽³⁷⁾ that the newer basalts of New South Wales were not all by any means contemporaneous. But there seems no reason to believe that volcanic activity was prolonged beyond the Pliocene Period in this State.

Geographical Distribution and Modes of Occurrence of the Various Series.

A reference to the map (Fig. 5) will indicate the approximate distribution of the lava-flows in eastern Australia and Tasmania as shown on Sir Edgeworth David's new geological map of Australia,⁽³⁸⁾ with slight modifications. They extend along a belt which is in places as much as 250 miles wide. In the absence of detailed survey the boundaries of the rock-masses cannot be regarded as at all accurate, but measurements from the map indicate the following areas to be at present covered with lavas, *etc.*:

| | | | | | | | | |
|-----------------|----|----|----|----|----|--------|--------|-------|
| Queensland | .. | .. | .. | .. | .. | 25,000 | square | miles |
| New South Wales | .. | .. | .. | .. | .. | 11,000 | " | " |
| Victoria | .. | .. | .. | .. | .. | 12,000 | " | " |
| Tasmania | .. | .. | .. | .. | .. | 1,600 | " | " |
| Total | | | | | | 49,600 | " | " |

It is evident that the original area covered has been much reduced by erosion, but the amount of this cannot well be estimated.

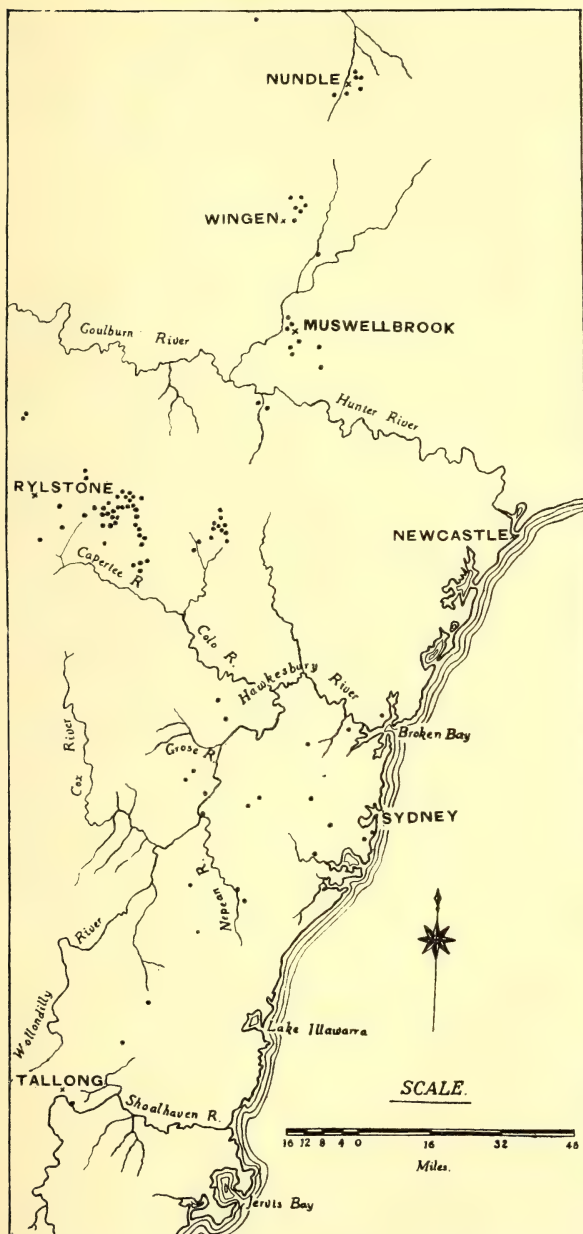


Fig. 5.—Map of Eastern Australia showing areas of Tertiary Lavas. (Leucite-basalt areas of N.S.W. are within circles.) Scale: 1 inch = about 375 miles.

No attempt has been made on the map to differentiate between various rock-types, but practically the whole area is covered with basic rocks, the acid and intermediate types, though widely distributed, only occupying a very small proportion of it.

Older Basic Lavas.

In the absence of definite petrological criteria there is no way by which rocks of the older basic series may be determined as such except their relations to certain other formations of known geological age. Unfortunately for the most part such criteria are lacking, so that the distribution of the older basic series is only imperfectly known. Among them may be mentioned the basalts overlying the older deep leads at Emmaville, and in the Inverell and Tingha districts, which are also largely overlain by laterite. To these may be added the residuals forming the ridge west of the Numeralla River, near Cooma, and the lavas overlying the Kiandra lead.

From considerations of geological time, and of the amount of erosion that must have taken place since their extrusion, it is permissible to say that the older basic series can exist only as remnants, and that the bulk of the Tertiary basic lavas must be assigned to the newer series.

Newer Basic Lavas.

These, by far the most abundant of the lavas, are distributed from the Queensland to the Victorian border, but about 80% of the total area occupied by them lies north of the Hunter-Goulburn valley. They form some of the highest land in the State, reaching heights of 5,000 feet in New England and the Mt. Royal Range,⁽³⁶⁾

while on the far North Coast and on the South Coast they come down to sea-level.⁽³⁹⁾

The surface on which the lavas were poured out was very diversified. In the Blue Mountain area, for instance, the relief was probably slight; elsewhere it was much more pronounced, with youthful and alluviated mature valleys as much as 300 or 400 feet deep, or even more. The flows were in places so thick as to fill the valleys completely and obliterate the original relief, producing a more or less flat plateau-like physiography.

Since their extrusion the flows have been affected, partly during Pliocene time, partly since the Kosciusko uplift, by river-erosion. In places valleys have been cut through them to a depth of 1,500 feet, as in eastern New England and the north of the Liverpool Range; elsewhere basalt-filled valleys have been re-eroded, flows have been reduced to isolated patches, and considerable areas have been entirely denuded of their basalt covering, doubtless where it was originally thin. Vivid and picturesque descriptions of the eroded basalt tablelands of New England have been given by Andrews.

Successive flows of lava are indicated by the flat-topped terraced hills so common in the maturely eroded basalt country, the terracing or "trap-featuring" being due to the erosion of alternately amygdaloidal and solid layers of basalt. Individual flows may be only fifteen to twenty feet thick, but exceptionally they may attain a thickness of 100 feet, and total thicknesses of 1,500 feet and more have been piled up in the Macpherson and Liverpool Ranges, the Barrington Plateau and the New England highlands.

It is doubtful whether the thickness of the lava was ever so great in other parts of the State. Certainly in

most places the present thickness is not generally more than a few hundred feet. About Cooma the greatest thickness shown by a natural section is about 400 feet.

Tuffs and other fragmental material are associated with the lavas only to a very slight extent. Occasionally layers of soil or of bole have been found separating flows.

The acid pitchstones included with the newer basic lavas are of small volume, and are confined mostly to the extreme north of New England. Richards describes some of them, notably that from Mt. Lindesay.⁽²⁸⁾ Their extrusion was of a violent nature, and agglomerates are not uncommon. A few other acid pitchstones are known, but their age is in doubt.

Older and Newer Basic Intrusives.

Of the older series the only representatives definitely known are the analcite-dolerite laccolith of the Nandewar Mountains and the essexite sill of Mount Jellore, near Mittagong. Raggatt and Whitworth⁽⁴⁰⁾ have recorded an analcite-dolerite sill from Murulla, near Wingen, intrusive into Upper Kamilaroi coal-measures capped by Triassic strata which are overlain by newer basalt. The sill is intersected by a basalt-dyke and a small neck, and the whole occurrence is in harmony with the view that the sill belongs to the older series. Physiographic and petrological considerations strongly suggest that the basic rocks capping Mounts Bocobel and Dangar are to be regarded as denuded sills belonging to this older series, and it is very possible that other isolated hills capped with dolerite, and rising well above the general level on which the later basalts were outpoured, are explicable in the same way. Mr. Leo J. Jones informs me that in the Cudgegong district Mts. Carcalong and Boiga are residuals essentially similar to Mt. Bocobel.

A study of microslides of rocks from the above-named intrusions suggests the possibility of establishing petrological criteria by means of which the older may be distinguished from the newer basic intrusions. The matter is more fully dealt with in the petrographical section, but may be put briefly here by saying that the older intrusions have teschenitic and the newer theralitic affinities. On these grounds I should be inclined to group with the Murulla sill the Savoy, Plashett, Fordwich and Carrington sills, in the Muswellbrook-Singleton district,⁽⁴⁰⁾ and the analcite-dolerite sill among the Kuttung strata at Currabubula.⁽⁴¹⁾ On the same grounds the Prospect intrusion near Parramatta⁽⁴²⁾ would be included among the older intrusions, and it is not improbable that other similar sills lie unrevealed beneath the great areas of Triassic sandstone to the north, south and west of the Sydney area.

These older dolerites are found in stratiform intrusions which may be of fairly considerable thickness. The Prospect mass has been estimated to be about 300 feet and the Savoy sill 275 to 300 feet. A thickness of nearly 500 feet of fine-grained dolerite caps Mount Dangar, and the remnant on top of Mount Bocobel is 350 feet, while Jensen estimates the dolerite laccolith in the Nandewars to be 700 feet thick.

The only newer dolerites definitely proved to be such are those occurring as sills and plugs amid the newer basalts of the Liverpool and Mount Royal Ranges. The dolerite-dykes of Mount Warrawalong⁽¹⁹⁾ and the theralitic plug near Bombala⁽⁴³⁾ appear to be associated with newer basalt. Others which may probably be placed in the same category for similar reasons, or on the score of petrological characteristics, are the nepheline-dolerite

sills of Nullo Mountain and of Mount Midderula, in the north-west Blue Mountain area,⁽²¹⁾ the basanitic sill (?) of Square Top, Nundle,⁽⁴⁴⁾ and the essexite plug of Goonoo Goonoo, the nepheline-dolerite from the Richmond Range near Kyogle,⁽⁴³⁾ and the dolerite plug or sill of Gragin Peak near Warialda.⁽³⁴⁾ Some of the Illawarra Coast sills may be placed here also. Mr. G. F. K. Naylor informs me that Billyrambija Hill, a few miles N.W. of Marulan, is a dolerite intrusion connected with newer basalt. But there are many dolerites, of alkaline type, about which it is impossible on our present knowledge to say whether they belong to the older or the newer series. The plugs of newer dolerite possibly represent the feeders of sills rather than of flows.

It would appear that the recognition of these two series of basic intrusives may be of some interest and importance in regard to the Tertiary physiographic and tectonic history of the eastern parts of this State.

Middle Series.

Sussmilch⁽⁴⁵⁾ has enumerated most of the principal occurrences and plotted their positions on a map.

The best known of the alkaline volcanic centres are those of the Canoblas, Warrumbungle and Nandewar Mountains, which have been studied in some detail. Kenny⁽⁴⁾ has lately recorded a number of plugs of alkaline trachyte forming isolated peaks in the Tambar Springs-Mullaley area, east of Coonabarabran, and flows and plugs of trachyte nearer that town, evidently an extension of the Warrumbungle volcanic area. South-west of the Warrumbungles, between Dubbo and Wellington, there are trachytic plugs and dykes.⁽³⁵⁾ The trachytic plug of Mount Jellore is of closely similar type to the others

mentioned, and to it are probably related trachytic dykes and necks at Mittagong. Trachytes have also been reported from near Goulburn. On petrological grounds the plugs of the Lansdowne district, north of Taree, are to be included in the Middle Series, also various trachytes in the far north of New England,⁽⁴⁶⁾ like the plugs, sills, *etc.*, of North and South Obelisk, Edinburgh Castle and Mount Wilson.

A couple of alkaline intrusions have been described from Illawarra District.⁽⁶⁾ The Jamberoo nepheline-syenite forms a sill about 60 feet thick in the bed of the Minumurra River, and a similar rock outcrops in Kangaroo Valley; the Dhruwalga sill, 250 feet thick, is of tinguaitite. Both of these are intrusive through the Upper Kamilaroi coal-measures, but they have affinities with other rocks of the Tertiary middle series, and are perhaps to be placed with them.

A wonderful series of tinguaitite-laccoliths have been described from the Barigan district.⁽⁴⁷⁾ No less than twelve of these have been mapped within an area of about 60 square miles. They have all arched up the Triassic and Kamilaroi strata on their flanks to a marked extent, and from the nature of their component rocks they are grouped with the middle series. The largest of the mapped intrusions has a basal area of about 1,200 acres and is at least 1,000 feet thick. Two other laccolithic intrusions were recently discovered during a reconnaissance trip by some of my colleagues and myself. The first forms an extensive outcrop probably a mile or more in diameter along the road about 8 miles east of Bylong and just west of the Kerribree Pass, and the Triassic strata around it are gently arched; the other is a little

west of the Bylong-Rylstone Road about N.E. of Stormy Mount, Barigan.

What is probably a plug of tinguaitite forms a symmetrical conical hill, the Sugarloaf, at Newstead North, near Inverell,⁽³⁴⁾ rising from a plateau of Tertiary older (?) basalt. A small dyke through the granite of the Kosciusko Plateau⁽⁹⁾ near Hedley Tarn is grouped in age with the other tinguaites on account of its composition, and the same is true of some tinguaitite dykes about Wellington.

Recent geophysical observations by Major E. H. Booth have confirmed the geological evidence of dipping strata that the microsyenite intrusion of Mount Gibraltar, at Bowral, is not a volcanic neck but a laccolith, probably asymmetrical, with an underlay to the east. At Mittagong in the valley of the Nattai River is a domed sölvbergite intrusion which is to some extent phacolithic, inasmuch as the underlying strata are also domed.

The distinction between intrusive and extrusive forms in the rocks of this middle series is not always clearly marked. Flows and tuff-beds there undoubtedly are in the Canoblas and Warrumbungle Mountains, but it is by no means impossible that some of the viscous alkaline magma solidified as plugs or mamelons of fine-grained trachytic rocks without any concomitant flows. The absence of all traces of trachyte-lava around some of these plugs, and the fact that the invaded strata are in places tilted into almost vertical positions, suggest that intrusion was the dominant process, rather than extrusion.

Basic Volcanic Necks.

These necks have a fairly wide though somewhat sporadic distribution (Fig. 6). David⁽¹¹⁾ has described



Fig. 6.—Map showing the chief volcanic necks belonging to the Newer Basic Series.

what he considers to be craters, and cones of lateritized tuff, from the Vegetable Creek (Emmaville) district associated with the older basalts, but apart from these the known centres of eruption are connected with the newer basic lavas. Possibly among these intrusions may be placed the Ruby Hill breccia-pipe, near Bingara.⁽⁴⁸⁾ Benson has recorded the existence of at least half-a-dozen basalt necks about Nundle,⁽⁴⁴⁾ associated with the newer basalts. He has also noted a small neck at Currabubula. Raggatt and Whitworth have recorded ten necks in the Hunter Valley between Jerry's Plains and Scone, and Raggatt has found others near Wingen. From the nature of the fillings, some lava, some breccia, these are in all probability Tertiary, though there is no external evidence on the point, the intrusions being through Palæozoic strata. Necks are particularly abundant in the north and north-western parts of the Blue Mountain area. Carne has recorded about 65 of them, and he states that in one area with a radius of four miles at least twenty points of eruption occur. The necks range from a few chains up to half-a-mile in diameter, and for the most part they are somewhat circular in plan. Some remnants of the original cones survive, notably at Tayan Peak. A small neck has been recently discovered a few miles E. of Bylong.

In the Sydney area about 20 necks have been recorded. Those at Dundas and Hornsby and the Basin near Mulgoa⁽⁴⁹⁾ are perhaps the best known, and they have been described in detail. Some of these are to the north, as at Woy Woy and Cowan. Others, as the Minchinbury neck⁽⁵⁰⁾ and that at Euroka Farm,⁽⁵¹⁾ are to the west, the farthest away forming The Valley at Valley Heights, on the Blue Mountains. To the south they have been recorded

as far as Glenlee and Mount Gilead. Some of these necks are subcircular in plan, but others, like those of Hornsby and the Basin, are notably elongated, with a greatest diameter of more than a mile. Some of the necks are breccia-filled and others contain lava.

On the southern part of the Central Plateau Jaquet⁽⁵²⁾ noted a small basalt neck between Bowral and Mittagong, and Mr. G. F. K. Naylor has discovered another forming the depression known as the Devil's Hole at Tallong.

This list of necks makes no pretensions to being exhaustive.

Basic Dykes and Minor Sills.

These have been mapped in the coastal areas from Newcastle as far south as Ulladulla and beyond. They are particularly abundant between Port Jackson and Port Hacking, and for some few miles north and south of Kiama. Dr. Ida A. Brown⁽⁵³⁾ has recorded basic dykes cutting through granite on the South Coast near Moruya, but their exact age is doubtful. On the Illawarra coast they are confined to a belt about 10 miles wide, though further north they are found thirty miles and more inland. From differences in the rock-types and the fact that some dykes are intersected by others, Harper was inclined to believe that they did not all fall in the same epoch of volcanic activity, and this may well be so. Carne has remarked on the inverse relation between the number of dykes and necks in the Blue Mountain area and about Sydney. He has recorded only seven dykes in the Western Coalfield, some of which are connected with necks. Raggatt and Whitworth have noted at least 40 basic dykes in the Muswellbrook-Singleton area which may be Tertiary, as well as several small sills.

These dykes are for the most part only a few feet wide, though they range from a few inches to more than 200 feet. They are difficult to detect except on rock-platforms or cliffs, or in railway- or road-cuttings. Owing to the mantle of soil, it has proved impossible to trace them for any distance.

A very common characteristic of the coastal dykes is that of side-stepping, which is admirably seen in plan on the rock-platforms. In the cliff-sections the dykes may sometimes when traced upwards be seen to taper out and disappear.

The tabulated lists published by the Geological Survey⁽⁶⁾ ⁽⁵⁰⁾ indicate that upwards of 270 dykes have been noted in the coastal belt between Broken Bay and Nowra, and more have been discovered since the publication of the lists, so that the total must be somewhere about 300. The trends of the great majority of these lie between E. 30° N. and E. 30° S.

Petrographical Notes.

Acid Pitchstones.

These are of minor importance as regards volume. In a general way the descriptions given by Richards for those in south-eastern Queensland apply equally to the New South Wales occurrences. Specimens from the head of the Clarence and Richmond Rivers include both holohyaline types and porphyritic pitchstones, the latter containing phenocrysts of quartz, acid plagioclase, orthoclase (?) and a pyroxene, probably hypersthene now pseudomorphed by iddingsite. Smeeth⁽⁵⁴⁾ records hypersthene from a Tweed River pitchstone. Perlitic cracking is common.

The perlitic pitchstone of uncertain age described by Jensen⁽¹⁷⁾ from near Boggabri contains only felspar among the phenocrysts, without quartz or pyroxene. It is associated with more or less crystalline rhyolites and is itself of somewhat toscanitic composition. A rhyolite glass, porphyritic in quartz and orthoclase, and enclosing fragments of trachyte and other lavas, outcrops in the Wonbangalan Range, 24 miles S.W. of Dubbo. This is a very fresh rock, and from the nature of its inclusions and its comparative proximity to other Tertiary lavas it may be assigned tentatively to the Tertiary era.

Alkaline Rocks of the Middle Series.

These include quite a wide range of types, both chemical and mineralogical, but they are most conveniently considered together. At the volcanic foci trachytes of various kinds probably bulk largest, with textures generally trachytic but sometimes orthophyric. A striking similarity characterizes the trachytes from different centres, as has been demonstrated by Jensen's descriptions and chemical analyses of a number of occurrences.

At the Canoblas Mountains the general sequence of extrusion appears to have been: comendites and trachytes with anorthoclase, riebeckite and arfvedsonite, and occasional quartz; more basic ægirine-trachytes and trachyandesites with abundant tuffs; porphyritic basalt, possibly allied to mugearite. In addition to lava-flows there are dykes and plugs of sölvbergite, *etc.*

The chief types found at the Warrumbungle Mountains are, in general order of eruption: riebeckite- and arfvedsonite-trachytes; ægirine-trachytes and phonolites with nepheline and nosean; olivine-trachydolerites and alkaline basalts.

In the Nandewar Mountains intrusion seems to have played a more important part. An eruption of arfvedsonite-trachyte and tuffs was followed by intrusion of sills of pulaskite and nordmarkite-porphyry, with extrusion of phonolites, and this by flows of alkaline andesite. The range of differentiation here appears to have been less than at the other centres.

The groundmass of many of the rocks at these volcanic foci is very fine-grained, and Jensen has mentioned doubtfully the presence of a number of rare minerals such as laaenite, wöhlerite, *etc.*, whose identity it would be hard to prove. The identity of former feldspathoids now completely pseudomorphed is also a matter of surmise.

From the dykes and plugs of alkaline rocks between Wellington and Dubbo sölvbergite or anorthoclase-trachyte, olivine-anorthoclase-ægirine-trachyte and quartz-trachyte have been identified, also an ægirine-microsyenite, which recalls somewhat that of Mount Gibraltar, Bowral.

From the alkaline plugs about Tambar Springs and Mullaley ægirine-trachyte and ægirine-augite-orthophyre have been noted.

Among the rocks forming the plug-like masses of the Lansdowne district it has been possible to recognise comendites, arfvedsonite-anorthoclase-trachyte, bostonite and a perlitic glass, probably trachytic, with microlites of potash feldspar.

The alkaline rocks of the far north of New England include arfvedsonite-quartz-trachyte, sölvbergite and ægirine-trachyte with analcite or sodalite.

An interesting series of intermediate eruptives, evidently closely related, occurs in the neighbourhood of

Bowral and Mittagong. The principal outcrop is that of Mount Gibraltar, a laccolith composed of ægirine-microsyenite with pneumatolytically-altered phases, intersected by narrow segregation-veins of pegmatitic aspect. In the same neighbourhood are two other intrusive masses, about $2\frac{1}{2}$ miles to the east and 3 miles to the north-east of Bowral respectively, composed of a rock perhaps best described as sölvbergite. A noteworthy feature of the sölvbergites is the conversion of ægirine in places into magnetite or hæmatite, apparently by magmatic fluids. The rocks link the microsyenites to certain finer-grained trachytic or bostonitic types appearing in dykes in the neighbourhood, and to a trachyte-breccia neck.

Seven or eight miles to the north-west of Mount Gibraltar Mount Jellore rises abruptly above the plateau-level. It is composed of ægirine-trachyte and arfvedsonite-quartz-trachyte. I am informed that further outcrops belonging to this series are to be found at Mount Colo, not far from Mt. Jellore.

In the nepheline-syenite sill in the Minumurra Valley, Illawarra district, anorthoclase is accompanied by nepheline and sodalite, and the dark minerals are ægirine-augite and biotite, with a little brown hornblende.

The Dhruwalga sill, also in the Minumurra River, is a trachytoid tinguaite composed largely of anorthoclase laths, with nepheline and sodalite, ægirine and arfvedsonite. There are also xenocrysts of deep brown hornblende which have reacted with the magma, and aggregates of magnetite and of soda-pyroxene and -amphibole. The presence of the xenocrysts may connect these sills with the coastal dykes rather than with the middle series.

The rocks of the Barigan laccoliths are very closely similar petrologically, being all of the nature of fine-grained trachytoid tinguaites mottled with characteristic dendritic and spiky aggregates of ægirine. Sodalite is present as well as occasional zeolites. The distribution of the sharply idiomorphic nepheline does not appear to be uniform in any one intrusion; specimens from the top of Stormy Mount show comparatively little, but those from near the base a good deal, while the converse is the case in the Porcupine intrusion. The texture of the Bald Mountain tinguaites, a few miles from Rylstone, approaches nephelinitoid owing to the greater proportion of the feldspathoid present.

The recently-discovered laccolith N.E. of Stormy Mountain is a fine-grained sodalite- (or analcite-) syenite-porphyry. The other mass near Kerribree Pass is perhaps best described as a sodalite-tinguaites with phenocrysts of anorthoclase; it recalls in some respects the nepheline-syenite-porphyry of Jamberoo.

Large dykes of a trachytoid ægirine-nepheline-tinguaites have been discovered both east and west of Wellington,⁽⁵⁵⁾ and an exactly similar rock outcrops at Dilabamble Trig. Station, near Dubbo,⁽⁵⁶⁾ and another at Jawbone, near Wellington. The ægirine-tinguaites of the Kosciusko dyke is a very dense hypocrySTALLINE rock with somewhat nephelinitoid texture.

Jensen has compared the chemical characters of many of the acid and intermediate flows from various centres, and it is unnecessary to give details here. The trachyte analysis shown in Table I is fairly representative.

The analyses of the tinguaites collected in Table I serve to emphasise the remarkable similarity of these rocks from widely separated localities. As compared with the

syenites they are rather extreme in the matter of alkalis, and they cannot be regarded as undifferentiated portions of a syenite magma. Other noteworthy features of the analyses are the dominance of Fe_2O_3 over FeO , the high Al_2O_3 and the exceptionally low TiO_2 and P_2O_5 .

TABLE I.

| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. |
|-------------------------------|-------|--------|-------|-------|--------|--------|--------|-------|
| SiO_2 | 55.82 | 53.30 | 53.62 | 52.40 | 59.49 | 54.50 | 55.16 | 60.73 |
| Al_2O_3 | 20.19 | 22.19 | 22.78 | 19.93 | 19.56 | 17.81 | 14.67 | 18.16 |
| Fe_2O_3 | 3.70 | 3.58 | 2.62 | 3.83 | 2.20 | 1.70 | 2.36 | 4.63 |
| FeO | 1.17 | 1.55 | 0.72 | 1.51 | 2.34 | 5.30 | 7.31 | 0.20 |
| MgO | 0.25 | 0.24 | 0.42 | 0.32 | 0.09 | 1.09 | 0.56 | 0.31 |
| CaO | 1.02 | 1.36 | 0.68 | 1.34 | 0.85 | 2.64 | 2.30 | 0.10 |
| Na_2O | 9.57 | 9.73 | 10.40 | 11.71 | 8.68 | 5.39 | 5.65 | 4.88 |
| K_2O | 5.60 | 5.74 | 5.22 | 4.10 | 5.29 | 6.08 | 6.97 | 6.21 |
| $\text{H}_2\text{O} +$ | 1.30 | 1.38 | 2.44 | 3.54 | 1.36 | 3.78 | 0.88 | 1.33 |
| $\text{H}_2\text{O} -$ | 0.15 | 0.38 | 0.22 | 0.23 | 0.18 | 0.54 | 0.85 | 0.72 |
| CO_2 | 0.04 | 0.02 | 0.07 | 0.21 | 0.04 | 0.30 | 1.50 | tr. |
| TiO_2 | 0.01 | abs. | 0.08 | — | 0.09 | 0.44 | 0.60 | 0.60 |
| ZrO_2 | 0.09 | 0.11 | 0.20 | — | 0.11 | abs. | — | — |
| P_2O_5 | 0.07 | 0.08 | 0.03 | tr. | 0.04 | 0.44 | 0.38 | abs. |
| SO_3 | 0.08 | 0.09 | 0.05 | abs. | abs. | 0.02 | 0.25 | — |
| Cl | 0.37 | 0.12 | 0.19 | 0.05 | 0.08 | tr. | 0.15 | 0.03 |
| MnO | 0.36 | 0.47 | 0.05 | 0.45 | tr. | 0.25 | 0.47 | 0.10 |
| etc. | 0.01 | 0.07 | | | | | 0.02 | |
| | 99.80 | 100.41 | 99.79 | 99.62 | 100.40 | 100.28 | 100.08 | 98.00 |
| Less O = Cl .. | 0.07 | 0.04 | 0.05 | 0.01 | 0.01 | — | 0.07 | |
| | 99.73 | 100.37 | 99.74 | 99.61 | 100.39 | 100.28 | 100.01 | |
| Sp. Gr. .. | 2.594 | 2.618 | 2.577 | 2.499 | 2.593 | 2.595 | 2.675 | |

I.—Tinguaite, Dhruwalgha Sill. Anal. J. C. H. Mingaye. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 341.

II.—Tinguaite, Pinnacles, Barigan. Anal. J. C. H. Mingaye. *Mem. Geol. Surv. N.S.W.*, Geol. 3, p. 239.

III.—Tinguaite, Porcupine Mount, Par. Barigan, Co. Phillip. Anal. J. C. H. Mingaye. *Mem. Geol. Surv. N.S.W.*, Geol. 3, p. 239.

IV.—Tinguaite, Kosciusko. Anal. F. B. Guthrie. *This Journal*, 36, 1902, p. 366.

V.—Phonolite, Dilabamblé Trig. Station, Dubbo. Anal. H. P. White. *Ann. Rept. Dept. Mines N.S.W.*, 1906, p. 177.

VI.—Nepheline-syenite, Kangaroo Valley. Anal. W. A. Greig. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 339.

VII.—Microsyenite, Mt. Gibraltar, Bowral. T. G. Taylor and D. Mawson, *this Journal*, 37, 1903, p. 341.

VIII.—Porphyritic Soda-trachyte, Warrumbungle Mts. Anal. H. I. Jensen. *Proc. Linn. Soc. N.S.W.*, 32, p. 616.

Card has called attention to the chemical similarity between the Jamberoo nepheline-syenite and the pneumatolytically-altered syenite of Mount Gibraltar, Bowral. Apart from this, there are no outstanding chemical similarities noticeable between the syenites, tinguaïtes and trachytic lavas, but field-association and similarity of mineral assemblages strongly suggest the common derivation of these rocks of the middle series.

Basic Rocks of Flows and Necks.

Owing to their petrographical resemblances, no attempt will be made systematically to separate the older and the newer basalts for purposes of description. Since the basalts of the necks are in large measure similar to those of the flows, they will be described here also.

These basic rocks may be divided into a number of types which in general merge into each other. The most abundant are those which for want of better names I am calling calcic and plateau-basalts, the latter being somewhat alkaline, and corresponding fairly closely to the type so named by Harker⁽⁶⁷⁾ and Tyrrell.⁽⁶⁶⁾

Calcic Basalts.

One of the most conspicuous types in the northern part of the State is a porphyritic or andesitic basalt which forms part of the newer basic series. Richards has described it from south-eastern Queensland at Burleigh Heads and Tweed Heads. It also outcrops at Byron Bay, Mullumbimby, Lismore and Cudgen. Inland it has been noted at Kyogle, near the head of the Clarence River and in the Sandilands Range, and the most southerly points from which it has been recorded are at the Ebor Falls, east of Armidale, and near Walcha. Jensen has described what appears to be a similar rock from the Nandewar

Mountains. The abundant phenocrysts of labradorite (about Ab_1An_1) are upwards of half-an-inch in length, and the groundmass consists mostly of andesine or labradorite and pale-augite either granular or subophitic. Olivine is present sparingly or not at all, and the felspar phenocrysts may have a sporadic distribution and may disappear altogether.

Another evidently calcic type which appears to have rather wide distribution contains a fairly large but variable proportion of glass. In a basalt from Tweed Heads much brownish-black glass encloses narrow plagioclase laths, olivine granules and a little brownish augite: a somewhat similar rock but with stouter felspars occurs at Black Head, Ballina, on the Richmond River, and another on the plateau near Apsley Falls.* Closely resembling these rocks is an olivine-basalt from Gulgong, and another has recently been found among the newer series by Mr. G. F. K. Naylor at Brayton, a few miles north of Marulan.

A modification of this general type is seen in some rocks from the town of Inverell, and from Oakey Creek, near it, which probably belong to the older basic series. These have very little olivine and some enstatite-augite, and the intersertal appearance of the rocks, with shadowy needles of felspar and brown augite embedded in a brown glass, recalls that of the tholeiites, with which there is little doubt they have affinities. There are two other rocks which should be mentioned here, in which the tholeiitic aspect is even more marked. One of these, from Yellow Pinch, Wolumla, South Coast, contains enstatite as well as augite, but no olivine; its field-occurrence, according to

* I am indebted for specimens of this and other basalts to Mr. F. A. Craft.

Dr. Ida Brown, is like that of flows of ordinary Tertiary basalt in the neighbourhood. A slide of a very closely similar rock from the Grenfell district appears in the collection of the Mining Museum, but its field-relations are unknown. Both of these rocks are almost identical in characters with an enstatite-tholeiite of Kangaroo Island, South Australia, which is believed to be Tertiary.

The chemical compositions of some of these rocks are given, with their norms, in Table II.

Plateau-basalts.

There are other basalts of widespread occurrence which are distinguished from the foregoing rocks by their generally higher content of olivine, a more strongly-coloured pyroxene, and a more elongated habit in the plagioclase. These are mostly holocrystalline, though hypocrySTALLINE representatives are found, with interstitial clear brown glass or with a palagonitic mesostasis containing skeletal ilmenite and much magnetite-dust. The grainsize varies from medium to very fine, and the rocks are not in general porphyritic. Occasionally the olivine is in microphenocrysts, and there may be two generations of pyroxene, while exceptionally, as at Mounts Tomah and Wilson, there may be phenocrysts of plagioclase up to $\frac{1}{4}$ -inch in length.

The most common type of fabric is a kind of intergranular, but in certain rocks there is a tendency for the augite packed in between the felspar laths to be in quite well-formed little stumpy prisms instead of granules. In the more felspathic of the fine-grained rocks a fluxional pilotaxitic fabric is frequently met with, while exceptionally the felspar is large and assumes a poikilitic habit towards the augite crystals. The ophitic fabric is not

TABLE II.

| | I. | II. | III. | IV. | V. |
|--------------------------------------|-------------|-------------|----------------|----------------|------------|
| SiO ₂ | 50·78 | 50·54 | 48·48 | 47·88 | 48·92 |
| Al ₂ O ₃ | 15·16 | 12·77 | 16·71 | 16·65 | 14·87 |
| Fe ₂ O ₃ | 2·36 | 2·50 | 5·93 | 2·45 | 3·99 |
| FeO | 10·01 | 8·01 | 5·96 | 7·08 | 7·44 |
| MgO | 4·43 | 5·89 | 4·19 | 7·91 | 5·73 |
| CaO | 6·46 | 9·24 | 7·02 | 9·25 | 7·26 |
| Na ₂ O | 3·54 | 3·33 | 3·38 | 2·64 | 3·42 |
| K ₂ O | 2·20 | 0·57 | 1·78 | 1·17 | 1·80 |
| H ₂ O+ | 1·32 | 1·96 | 1·44 | 1·38 | 1·56 |
| H ₂ O- | 0·75 | 1·24 | 2·07 | 1·02 | 0·82 |
| CO ₂ | 0·01 | 2·07 | 0·04 | 0·04 | 0·09 |
| TiO ₂ | 2·60 | 1·80 | 2·50 | 1·74 | 2·78 |
| P ₂ O ₅ | 0·34 | 0·23 | 0·59 | 0·36 | 0·59 |
| MnO | 0·14 | 0·11 | 0·12 | 0·22 | 0·29 |
| SO ₃ | 0·15 | abs. | 0·10 | 0·03 | 0·08 |
| Cl | 0·02 | abs. | 0·07 | 0·05 | 0·02 |
| etc. | 0·13 | 0·05 | 0·11 | 0·17 | 0·17 |
| Less O | 100·40 — | 100·31 — | 100·49 0·01 | 100·04 0·01 | 99·83 — |
| | 100·40 | 100·31 | 100·48 | 100·03 | 99·83 |
| Sp. Gr. | 2·795 | 2·808 | 2·761 | 2·858 | 2·865 |
| | I. | II. | III. | IV. | V. |
| Quartz | — | 4·80 | 3·00 | — | — |
| Orthoclase | 12·79 | 3·34 | 10·56 | 7·23 | 10·56 |
| Albite | 28·30 | 27·77 | 27·77 | 22·01 | 28·30 |
| Anorthite | 20·02 | 18·35 | 25·58 | 30·02 | 20·29 |
| Thenardite | 0·28 | — | 0·14 | — | 0·14 |
| Halite | — | — | 0·12 | — | — |
| Diopside | 8·75 | 10·72 | 4·64 | 10·75 | 11·44 |
| Hypersthene | 18·57 | 19·02 | 10·42 | 10·37 | 12·83 |
| Olivine | 0·35 | — | — | 9·36 | 1·56 |
| Magnetite | 3·48 | 3·71 | 8·58 | 3·48 | 5·80 |
| Ilmenite | 5·02 | 3·50 | 4·71 | 3·19 | 5·32 |
| Apatite | 0·67 | 0·34 | 1·34 | 1·01 | 1·34 |
| Calcite | — | 4·80 | — | — | 0·20 |

I.—Olivine-basalt (Camptonose, (II)III.5.3.4), Tweed River Heads. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 304.

II.—Olivine-basalt, (Ornose, III."5.3.(4)5), Rob Roy Gully, Inverell. *Ann. Rept. Dept. Mines N.S.W.*, 1908, p. 184.

III.—Olivine-basalt, (Andose, II.5.3.4), Black Head, Ballina, Richmond River. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 304.

IV.—Olivine-basalt, (Auvergnose, (II)III.5.4".4), Gulgong. Anal. H. P. White. *Rec. Geol. Surv. N.S.W.*, 7, p. 304.

V.—Olivine-basalt, (Camptonose, (II)III.5.3.4), Canoblas Mountains. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 304.

uncommon, even in quite fine-grained rocks, and this may be combined with a fluxional arrangement of the felspars. Some of the coarser types have quite a doleritic aspect, and on their texture might be described as dolerites, although they occur as flows, but in the field it is difficult to tell the mode of occurrence of some of these coarser types, while some intrusions are composed of relatively fine-grained rock.

Labradorite is in general the most abundant mineral, but augite may equal or even exceed it. The augite varies in colour from greyish-green through purplish-brown to a distinct violet, but it is never colourless or weakly coloured. The olivine, fresh or rather serpentinised, has a very large optic axial angle with positive birefringence. In some of the Blue Mountain basalts the olivine is fragmental and quite evidently forms xenocrysts. Among the minor constituents a little interstitial analcite or other zeolite appears, and this is probably present in many rocks in which it cannot be detected by optical means; the proportion of analcite varies quite notably even in the same flow, and some of the rocks might be called analcite-basanites. They are found amongst the

older basalts of the Tingha district and the newer basalts of other parts of the New England plateau, and in the Liverpool and Mt. Royal Ranges. The rocks described from the flows and necks of the north-western Blue Mountains area are largely of the same type, also the newer basalts of Bathurst, and some from the neighbourhood of Dubbo. Here, too, should be placed the basalts of the south-central plateau, as about Mittagong and Moss Vale, Exeter, Wingello and Tallong, of the Robertson Plateau, and of the middle South Coast about Ulladulla and Moruya. We find them also on the Southern Plateau about Cooma, Nimmitabel and Kiandra. Indeed they appear to form the most common type in the central and southern plateaux, and are abundant in the New England plateau as well, though here the other types enumerated above would seem to have increasing importance towards the north.

There is no hard-and-fast line to be drawn between the calcic types and the plateau-type, either chemical or mineralogical. For instance in a series of specimens (for which I am indebted to Mr. J. M. Rayner) from some of the flows overlain by laterite (and therefore presumably belonging to the older series) in the Tingha district olivine is plentiful, and texturally the rocks are similar to some of the plateau-basalts, but in some the pyroxene is of the nature of enstatite-augite, whereas in others it is distinctly purplish-brown, and in these latter rocks there is a little interstitial zeolite. In the Orange district, too, are calcic olivine-basalts, associated with others of plateau-type.

TABLE III.

| | I. | II. | III. | IV. | V. | VI. |
|--------------------------------------|-------|--------|--------|--------|--------|--------|
| SiO ₂ | 43·31 | 44·38 | 44·57 | 44·66 | 45·06 | 45·88 |
| Al ₂ O ₃ | 16·68 | 16·18 | 15·30 | 13·37 | 14·60 | 17·16 |
| Fe ₂ O ₃ | 2·31 | 1·94 | 3·20 | 2·10 | 2·60 | 3·03 |
| FeO | 9·00 | 8·54 | 7·83 | 8·01 | 9·00 | 7·57 |
| MgO | 10·56 | 10·30 | 10·04 | 13·84 | 9·64 | 6·26 |
| CaO | 7·95 | 9·20 | 10·00 | 8·88 | 9·86 | 7·20 |
| Na ₂ O | 2·94 | 2·55 | 1·94 | 3·15 | 2·90 | 4·08 |
| K ₂ O | 0·97 | 1·50 | 1·39 | 2·16 | 0·85 | 1·78 |
| H ₂ O+ | 1·72 | 1·99 | 3·21 | 1·75 | 2·73 | 3·17 |
| H ₂ O- | 0·88 | 0·74 | 1·09 | 0·23 | 0·55 | 0·88 |
| CO ₂ | 0·03 | 0·04 | 0·01 | 0·09 | 0·05 | 0·60 |
| TiO ₂ | 2·20 | 1·94 | 1·01 | 1·60 | 1·55 | 2·24 |
| P ₂ O ₅ | 0·65 | 0·31 | 0·41 | 0·57 | 0·61 | 0·19 |
| MnO | 0·43 | 0·26 | 0·29 | — | 0·19 | 0·24 |
| SO ₃ | 0·05 | 0·05 | abs. | — | — | 0·09 |
| BaO | tr. | 0·07 | 0·05 | — | — | 0·13 |
| etc. | 0·13 | 0·06 | 0·09 | — | 0·04 | 0·11 |
| | 99·81 | 100·05 | 100·43 | 100·41 | 100·23 | 100·61 |
| | 2·995 | 2·927 | 2·907 | 2·939 | 2·911 | 2·898 |

| | I. | II. | III. | IV. | V. | VI. |
|----------------|-------|-------|-------|-------|-------|-------|
| Orthoclase .. | 6·12 | 8·90 | 8·34 | 12·79 | 5·56 | 10·56 |
| Albite | 18·34 | 13·10 | 15·72 | 6·29 | 18·34 | 28·30 |
| Anorthite .. | 29·47 | 28·36 | 28·91 | 15·85 | 23·91 | 23·63 |
| Nepheline .. | 3·41 | 4·54 | 0·28 | 11·08 | 3·41 | 3·12 |
| Thenardite .. | — | — | — | — | — | 0·14 |
| Diopside | 4·94 | 12·55 | 14·55 | 19·30 | 17·33 | 3·83 |
| Olivine | 25·72 | 22·46 | 20·77 | 25·58 | 20·26 | 15·89 |
| Magnetite .. | 3·25 | 2·78 | 4·64 | 3·02 | 3·71 | 4·41 |
| Ilmenite | 4·26 | 3·65 | 1·98 | 3·04 | 2·89 | 4·26 |
| Apatite | 1·34 | 0·67 | 1·01 | 1·34 | 1·34 | 0·34 |
| Calcite | — | — | — | 0·20 | 0·10 | 1·40 |

I.—Basalt, (Auvergnose, "III.5.(3)4.4), "Woodlands". T. G. Taylor and D. Mawson. *Proc. Linn. Soc. N.S.W.*, 37, 1903, p. 341.

II.—Olivine-basalt, (Auvergnose, "III."5.(3)4.4), Mt. Apsley, near Bathurst. Anal. H. P. White. *Rec. Geol. Surv. N.S.W.*, 7, p. 304.

III.—Analcite-olivine-basalt, (Auvergnose, III.5.4."4), Robertson Flow, 5 miles west of Jamberoo. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 288.

IV.—Olivine-basalt, (Limburgose, III.6."3.4), Bald Hills, Hill End. Anal. H. P. White. *Ann. Rept. Dept. Mines, N.S.W.*, 1911, p. 198.

V.—Olivine-basalt (Camptonose, III."5.3(4).4"), 2½ miles along Cooma-Jindabyne Road. *Proc. Linn. Soc. N.S.W.*, 34, 1909, p. 314.

VI.—Olivine-basalt (Andose, II".5.3.4), Volcanic Neck, Dundas. Anal. H. P. White. *Rec. Geol. Surv. N.S.W.*, 7, p. 230.

The chemical compositions of some of these rocks are given in Table III. The proportion of nepheline in the norms varies, denoting a varying degree of alkalinity. The table illustrates the close similarity between the rocks of the central and those of the southern plateau.

Glassy Rocks.

Associated with the basalts there are in various places tachylytic phases. In Inverell, apparently associated with the newer flows, is a spherulitic tachylyte, and other specimens have been described from Vegetable Creek and Carcoar.⁽²⁴⁾ An augite has been found at Gulgong, and at Lucknow, near Orange, there is a basalt glass crowded with microlites of augite. Card has described from Mt. Coriaday, in the north-west Blue Mountain area, a rock which texturally and mineralogically should be called a limburgite, being composed of olivine and brown augite phenocrysts in a clear yellowish-brown glassy base crowded with augite-microlites. This rock shows alkaline affinities in the presence of analcite.

Nepheline-basanites and Nepheline-basalts.

In some of the olivine-basalts, particularly those of the Blue Mountain area, nepheline appears in small propor-

tion. These rocks grade into varieties in which the brown or violet-brown augite is much more conspicuous than felspar, and these again into others from which felspar is entirely absent. These nepheline-basalts are, as might be expected, very basic or ultrabasic. They are generally fine-grained to very fine, and often microporphyritic in olivine, which is of a ferriferous type with negative birefringence. The augite in the more alkaline types is purplish-brown, and the crystals become elongated, but in some of the nepheline-basalts it is in long slender crystals of a light-green colour, evidently ægirine-augite. The nepheline is generally interstitial, but is occasionally idiomorphic, and may then be accompanied by analcite. The nepheline-basanites and -basalts occur both as flows and as neck-fillings, sometimes in association with normal plateau-basalt. At least fifteen of the necks described by Carne from the Blue Mountain area contain nepheline, and there are outlying separate flows of nepheline-basalt, as at Ulan, Mt. Muruin and Yerranderie. Nepheline-bearing basalts have been reported from Ulamambri near Coonabarabran, and Mr. H. G. Raggatt has found them as far west as Sebastopol, near Junee, while in the north a very fine-grained nepheline-basalt forms the topmost lava-flow $1\frac{1}{2}$ miles east of Walcha Road, and a basanite occurs along the Armidale-Kempsey Road between Wollomombi and Oakey Creek. The most southerly nepheline-basalt yet discovered outcrops 4 miles N.W. of Wingello; in this the abundant nepheline is to some extent poikilitic.

The nepheline-basalts grade into rocks from which felsic minerals are almost entirely absent. One of these occurs as a small dyke on the road near Inspiration Point, at Jenolan Caves. There are no Tertiary rocks near it, but on the score of its freshness it is classed with them.

It is composed of olivine-phenocrysts in a groundmass of brown augite granules, with a very little interstitial material which is almost certainly nepheline; it would seem to be closely allied to the ankaramites and oceanites.

From Glenugie Peak, Mt. Elaine, near Grafton, comes another of these ultrabasic types. I do not know the mode of occurrence of this rock, but there appear to be three phases of it, two of which, a finer and a coarser, are composed of olivine and augite with a very little interstitial plagioclase and analcite, while the third is an analcite-basanite.

A rock which seems to be unique among known basalts in the State is that described by Card from Mt. McIong (Blue Mountain area) as a trachytic basalt. It appears mainly as a fine-textured aggregate of felspar laths, apparently oligoclase and orthoclase, with pale-green augite and some olivine. According to the chemical analysis, there must be nepheline as well, but it cannot be detected optically. As suggested elsewhere, it appears to have affinities with the mugearites.

Leucite-basalts.

Although the localities in which these occur are quite isolated from each other, there is a general similarity in the characters of all the rocks. The abundant leucite is generally fresh, the pyroxene is a weakly greenish-coloured augite, and the micro-porphyrritic olivine is rich in the fayalite molecule. A little interstitial nepheline is present in most of the rocks.

A feature of the leucite-basalts from Byrock and Lake Cudgellico is the presence of considerable biotite, and this mineral appears as a minor constituent in most of the others, suggesting that some of the occurrences are

neck-fillings rather than flows, though in part, at all events, the Byrock leucite-basalt is a flow, since it overlies old river-gravels.

TABLE IV.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|--------------------------------------|--------|--------|-------|--------|--------|-------|--------|
| SiO ₂ | 43·58 | 44·68 | 45·18 | 49·82 | 43·56 | 41·38 | 41·90 |
| Al ₂ O ₃ | 8·08 | 11·43 | 9·31 | 17·53 | 8·18 | 13·09 | 13·90 |
| Fe ₂ O ₃ | 5·00 | 7·00 | 6·31 | 4·30 | 2·40 | 5·80 | 3·10 |
| FeO | 5·77 | 4·67 | 4·08 | 7·11 | 11·15 | 7·07 | 8·82 |
| MgO | 12·91 | 10·25 | 10·77 | 3·02 | 18·49 | 8·30 | 13·72 |
| CaO | 8·88 | 9·44 | 8·56 | 5·26 | 10·34 | 9·92 | 9·66 |
| Na ₂ O | 0·90 | 1·56 | 1·73 | 5·90 | 1·65 | 4·23 | 3·51 |
| K ₂ O | 5·99 | 5·68 | 6·93 | 2·55 | 0·90 | 0·72 | 1·04 |
| H ₂ O + | 1·95 | 2·73 | 1·01 | 1·31 | 1·77 | 4·44 | 1·47 |
| H ₂ O - | 1·15 | 0·77 | 0·55 | 0·30 | 0·15 | 0·52 | 0·33 |
| CO ₂ | 0·11 | 0·20 | 0·17 | 0·04 | 0·04 | 0·04 | 0·27 |
| TiO ₂ | 4·64 | 0·84 | 4·36 | 2·04 | 0·92 | 3·28 | 1·25 |
| P ₂ O ₅ | 0·62 | 0·66 | 0·51 | 0·88 | 0·40 | 0·77 | 0·96 |
| MnO | 0·21 | 0·11 | tr. | 0·15 | 0·19 | 0·11 | 0·19 |
| NiO, CoO | 0·08 | tr. | abs. | abs. | abs. | 0·02 | 0·20 |
| BaO | 0·32 | 0·02 | 0·30 | 0·03 | abs. | 0·11 | abs. |
| etc. | 0·06 | 0·15 | 0·10 | 0·04 | 0·14 | 0·04 | 0·04 |
| Less O = Cl .. | 100·25 | 100·19 | 99·87 | 100·28 | 100·28 | 99·84 | 100·36 |
| | 100·25 | 100·17 | 99·86 | 100·27 | 100·26 | 99·84 | 100·36 |
| Sp. Gr. .. | 2·897 | 2·944 | 2·980 | 2·821 | 3·177 | 2·883 | 3·067 |

| | I. | II. | III. | IV. | V. | VI. | VII. |
|----------------|-------|-------|-------|-------|-------|-------|-------|
| Orthoclase .. | 16·68 | 23·91 | 13·34 | 15·01 | 5·56 | 3·89 | 6·12 |
| Albite | — | — | — | 36·68 | 4·72 | 18·86 | 6·81 |
| Anorthite .. | — | 7·23 | — | 13·90 | 12·51 | 14·73 | 19·18 |
| Nepheline .. | 4·26 | 7·10 | 5·11 | 6·95 | 4·54 | 9·09 | 12·21 |
| Leucite | 14·82 | 7·85 | 21·36 | — | — | — | — |
| Halite | — | 0·12 | — | — | 0·12 | — | — |
| Diopside | 31·53 | 26·08 | 29·81 | 6·38 | 28·79 | 23·00 | 16·49 |
| Olivine | 12·39 | 10·58 | 9·17 | 8·08 | 35·85 | 7·67 | 27·15 |
| Haematite .. | 0·64 | — | 4·48 | — | — | — | — |
| Acmite | — | — | 4·16 | — | — | — | — |
| Magnetite .. | 6·26 | 10·21 | 0·46 | 6·26 | 3·48 | 8·35 | 4·41 |
| Ilmenite | 8·82 | 1·52 | 8·36 | 3·80 | 1·67 | 6·23 | 2·43 |
| Apatite | 1·34 | 1·68 | 1·34 | 2·02 | 1·01 | 2·02 | 2·35 |
| Calcite | 0·20 | 0·50 | 0·50 | — | — | — | 0·70 |

I.—Leucite-basalt, (Montrealose, (III) IV.2.2.2.2.), El Capitan. Anal. H. P. White. *Rec. Geol. Surv. N.S.W.*, 7, p. 302.

II.—Leucite-basalt, (Kajanose, III.6".2.2), Lake Cudgellico. Anal. W. A. Greig. *Ann. Rept. Dept. Mines N.S.W.*, 1915, p. 196.

III.—Leucite-basalt, (Chotose, III(IV).".8.1.2), Byrock. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 302.

IV.—"Trachytic Basalt," (Akerose, II.5(6).2.4), Mt. Molong. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 6, p. 93.

V.—"Limburgite," (Rossweinoose, IV.3.1."2.2), Glenugie Peak, Grafton. Anal. W. A. Greig. *Ann. Rept. Dept. Mines*, 1915, p. 196.

VI.—Nepheline-monchiquite, (Bekinkinose, III.6."3.(4)5, Top Hole Neck, Par. Putty. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 6, p. 93

VII.—Nepheline-basalt, (Limburgose, III.6.3.4"), Mt. Muruin. Anal. W. A. Greig. *Ann. Rept. Dept. Mines N.S.W.*, 1923, p. 97.

The chemical composition of the basanites and felspathoid-basalts is illustrated in Table IV. Low silica and alumina, and occasional high magnesia, are their outstanding characteristics. Potash is lower in the leucite-basalts than in similar rocks in other parts of the world.

Basic Volcanic Necks.

Those which are lava-filled are composed of basalt exactly similar to that of the flows, as described above. Nepheline-basalts and -basanites are found in many of the Blue Mountain necks. The basalt in the Dundas neck, near Sydney, contains nepheline in the norm, though it has not been detected modally; chemically it closely resembles the basalt of the Mt. Tomah (Blue Mountains) flow. Other neck-fillings are analcite-basanites, and the Tayan Pic neck contains crinanite.

The breccia which fills many of the necks is composed of very varied material. The nature and relations of some of it will be discussed in another section.

Older Basic Intrusives.

These have many characteristics in common, which nevertheless do not preclude a certain degree of variation. Some of the intrusions show evidences of considerable differentiation, which has expressed itself in the form of more acid and sometimes more basic phases. The best-known example is that of the Prospect sill, and a detailed

description of the Savoy sill in the Muswellbrook area has lately been published. Some of the sills show chilled margins, the rock being basaltic in texture, others are of fairly uniform grain throughout. Though the proportion of analcite is sometimes low, the rocks are on the whole teschenitic in affinities, being devoid of the ophitic fabric of the crinanites, while olivine is often absent. The other criteria proposed by Tyrrell⁽⁵⁸⁾ to separate the teschenite and the crinanite suites appear to break down when applied to these rocks, inasmuch as their light differentiates are intermediate in character, like those of the crinanites, and not basic like the lugarite associated with the teschenites. Essexitic affinities are indicated by the presence of orthoclase and occasional biotite in some of the rocks or in their acid differentiates. There is generally more or less magmatic alteration, resulting in the presence of much chlorite and in the zeolitisation of the feldspars. Olivine may or may not be present. The augite is sometimes of a marked violet-brown tint, but in other cases the violet component is only faint as at Savoy,⁽⁵⁷⁾ Prospect and Jellore. Skeletal ilmenite is common. Interstitial natrolite in radiating masses may accompany the analcite and partially replace the plagioclase. In a few of the rocks there are slight evidences of a period of interstitial crystallisation, and in the interstitial spaces may be seen small orthoclase-laths and a little green pyroxene as well as apatite and zeolites.

Only in one of the sills, that of Mt. Jellore, is an ultra-basic phase visible, a picrite, whose mode of occurrence has not been investigated in detail. It is free from the natrolite and analcite present in other parts of the sill. The Prospect sill is not exposed right down to its base, but from the variation of the olivine-content in different

parts of the exposed portions it would almost be safe to predict an ultrabasic differentiate at depth, as in the Lugar sill of Ayrshire.

The light differentiates are generally composed of acid plagioclase and orthoclase with dark minerals like biotite, barkevikite or a soda-pyroxene, and there may be interstitial analcite. But in the Savoy sill the acid phase, which is believed to be the result of differentiation before injection, contains interstitial quartz and micropegmatite. Chemical analyses of two of these are given in Table V.

The basic rock capping Mt. Dangar is considered to be a denuded sill rather than a flow because of the fact that it contains a little biotite and traces of interstitial crystallisation of green pyroxene, features characteristic of intrusions rather than flows. The rock is medium-grained, with violet augite ophitically enwrapping plagioclase laths averaging about 1 mm. long. There is a little interstitial zeolite.

Chemical analyses of some of the rocks of this older intrusive series are given in Table V; they show the composition to be very variable, but with one exception the rocks are not of extreme type.

Newer Basic Intrusives.

These present distinct differences from the rocks of the older series, and like the latter they differ among themselves. Differentiation does not appear to have attained such a wide range as in the older intrusions, perhaps because of a relative lack of volatile constituents, particularly water, in the magma. Possibly for the same reason the rocks as a whole are fresher, not having been subjected to much deuteric alteration.

Analcite is characteristically absent in the rocks examined, with a few exceptions, and nepheline takes its

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TABLE V.

| | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. |
|--------------------------------|--------|--------|--------|-------|--------|-------|--------|--------|--------|
| SiO ₂ .. | 45.58 | 41.05 | 43.06 | 46.26 | 58.82 | 39.91 | 46.22 | 49.50 | 60.76 |
| Al ₂ O ₃ | 17.31 | 12.27 | 16.31 | 13.36 | 16.91 | 13.67 | 9.33 | 16.46 | 14.23 |
| Fe ₂ O ₃ | 3.20 | 6.39 | 5.40 | 2.34 | 2.40 | 6.55 | 5.85 | 3.70 | 5.40 |
| FeO .. | 8.37 | 11.07 | 7.61 | 10.53 | 4.59 | 8.98 | 7.39 | 6.12 | 0.99 |
| MgO | 3.78 | 6.38 | 5.49 | 8.87 | 0.88 | 11.96 | 3.08 | 5.75 | 0.80 |
| CaO .. | 9.30 | 10.96 | 9.37 | 9.18 | 2.42 | 6.18 | 10.80 | 8.14 | 4.36 |
| Na ₂ O | 4.35 | 2.43 | 3.12 | 3.27 | 6.74 | 1.28 | 3.21 | 4.40 | 5.30 |
| K ₂ O .. | 2.52 | 0.53 | 1.07 | 1.23 | 2.96 | 0.66 | 1.80 | 1.15 | 3.67 |
| H ₂ O + | 2.86 | 3.58 | 2.93 | 2.08 | 1.98 | 3.74 | 2.30 | 2.69 | 1.47 |
| H ₂ O - | 0.44 | 0.44 | 1.16 | 0.15 | 0.56 | 3.66 | 0.94 | 0.87 | 0.35 |
| CO ₂ .. | abs. | 0.03 | 1.36 | 0.06 | 0.54 | 0.40 | 4.46 | 0.16 | 1.60 |
| TiO ₂ | 1.55 | 4.39 | 2.46 | 1.78 | 1.14 | 1.75 | 3.70 | 0.76 | 0.90 |
| P ₂ O ₅ | 0.54 | 0.19 | 0.32 | 0.42 | 0.34 | 0.61 | 0.80 | 0.48 | 0.26 |
| MnO | 0.18 | 0.17 | 0.23 | 0.12 | 0.13 | 0.18 | 0.32 | 0.16 | 0.18 |
| BaO .. | 0.02 | abs. | 0.02 | 0.05 | — | abs. | 0.24 | abs. | abs. |
| SO ₃ .. | 0.11 | — | — | 0.13 | — | tr. | 0.32 | abs. | abs. |
| S .. | abs. | 0.35 | 0.26 | abs. | — | 0.20 | 0.10 | abs. | abs. |
| Cr ₂ O ₃ | abs. | tr. | — | 0.02 | — | 0.21 | 0.02 | abs. | abs. |
| etc. .. | 0.05 | 0.08 | 0.13 | 0.07 | 0.01 | 0.02 | 0.05 | — | — |
| Less O | 100.16 | 100.31 | 100.30 | 99.90 | 100.42 | 99.96 | 100.93 | 100.34 | 100.27 |
| | — | — | — | — | — | 0.10 | 0.05 | — | — |
| | 100.16 | 100.31 | 100.30 | 99.90 | 100.42 | 99.86 | 100.88 | 100.34 | 100.27 |
| Sp. Gr. | 2.776 | 3.058 | 2.814 | 2.947 | 2.665 | 2.891 | 2.801 | 2.793 | 2.666 |

| | I. | II. | III. | IV. | V. | VI. | VIII. | IX. |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Quartz .. | — | — | — | — | 1.56 | — | — | 1.18 |
| Orthoclase .. | 15.01 | 2.78 | 6.67 | 7.23 | 17.79 | 3.89 | 7.23 | 21.68 |
| Albite .. | 13.62 | 18.34 | 26.20 | 20.96 | 57.11 | 11.00 | 36.68 | 44.54 |
| Anorthite .. | 20.57 | 21.41 | 27.24 | 18.35 | 6.95 | 24.74 | 21.68 | 4.17 |
| Nepheline .. | 12.21 | 1.14 | — | 3.41 | — | — | 0.28 | — |
| Thenardite .. | 0.14 | — | — | 0.14 | — | — | — | — |
| Diopside .. | 18.21 | 26.02 | 6.92 | 19.72 | — | — | 10.57 | 4.44 |
| Corundum .. | — | — | — | — | — | 1.73 | — | — |
| Hypersthene .. | — | — | 2.69 | — | 6.95 | 29.24 | — | — |
| Olivine .. | 8.16 | 7.87 | 9.74 | 19.74 | — | 6.33 | 11.98 | — |
| Magnetite .. | 4.64 | 9.28 | 7.89 | 3.25 | 3.48 | 9.51 | 5.34 | 1.16 |
| Ilmenite .. | 2.89 | 8.36 | 4.71 | 3.50 | 2.13 | 3.19 | 1.52 | 1.67 |
| Apatite .. | 1.34 | 0.34 | 0.67 | 1.01 | 0.67 | 1.34 | 1.34 | 0.67 |
| Calcite .. | — | — | 3.20 | 0.10 | 1.20 | 0.90 | 0.50 | 3.60 |
| Pyrites .. | — | 0.60 | 0.26 | — | — | 0.36 | — | — |
| Chromite .. | — | — | — | — | — | 0.22 | — | — |
| Haematite .. | — | — | — | — | — | — | — | 4.64 |

I.—Analcite-dolerite (Salemose, II(III).6."3.4), Fordwich Sill, Broke. Anal. W. A. Greig. *Ann. Rept. Dept. Mines N.S.W.*, 1928, p. 137.

II.—Analcite-dolerite (Auvergnose, III.5.(3)4.(4)5), Prospect. Anal. J. C. H. Mingaye. *This Journal*, 45, 1911, p. 483.

III.—Analcite-dolerite (Camptonose, (II)III.5.3(4).4), Prospect. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 230.

IV.—Analcite-dolerite (Camptonose, (II)III."5.3.4), Prospect. Anal. J. C. H. Mingaye. *This Journal*, 45, 1911, pp. 504-5.

V.—Analcite-dolerite (Aplitic phase), Prospect. Anal. H. P. White. This Journal, 45, 1911, pp. 504-5. (Akerose, (I)II.5".(1)2.5.)

VI.—Picrite (Auvergnose, III.5.4.4), Jellore Creek, Mittagong. T. G. Taylor and D. Mawson. This Journal, 37, 1903, p. 341.

VII.—Essexite, Jellore Creek, Mittagong. T. G. Taylor and D. Mawson. This Journal, 37, 1903, p. 341.

VIII.—Dolerite (Andose, II".5.3.4(5)), Savoy Sill. Anal. W. A. Greig. *Ann. Rept. Dept. Mines N.S.W.*, 1930, p. 88.

IX.—Syenite, Savoy Sill. Anal. W. A. Greig. *Ann. Rept. Dept. Mines*, 1930, p. 88.

place as a prominent constituent, hence the rocks are more closely allied to the theralites, essexites and trachydolerites than to the teschenites. Many of them, however, show traces of a mesostasis, and so are more naturally grouped with the dolerites than with the plutonic rocks. The texture is variable. In the Square Top (Nundle) rock and some of those from the Mt. Royal Range augite dominates the rock in rather stoutish idiomorphic crystals up to and exceeding 4 mm. in length, which may be aggregated. In these rocks the lath-shaped plagioclase is of much smaller dimensions. In other rocks, as that of Gragin Peak, the felspar in elongated prisms averaging up to 2.5 to 3 mm. in length dominates the rock, sometimes with a kind of fluxional arrangement, and the augite in small prisms is interstitially disposed to the felspar.

Augite is strongly titaniferous, and the bigger crystals are well-zoned and may show hour-glass structure; olivine is always present and is generally fresh; plagioclase is a medium labradorite. Nepheline is usually interstitial and in small crystals and grains, but in the Wharton's Mill rock in the Mt. Royal Range it is in crystals comparable with plagioclase, and here it is accompanied by a notable proportion of interstitial analcite.

The interstitial material of late crystallisation may also comprise orthoclase (sometimes in little cervicorn

crystals), apatite, ilmenite and green pyroxene. This interstitial crystallisation appears to be more common than in the older basic intrusives, and is found even in the finer-grained types such as those from Nullo Mountain and Mt. Midderula. In some, as those from the Richmond Range, Bombala and Billyrambija, it may form as much as 20% of the rock.

Chemically these later dolerites are seen (Table VI) to be rather extreme alkaline basic types, as indicated by their norms, and by the names of their subranges. Among those whose analyses are available there are many differences, but some of them resemble certain of the Blue Mountain nepheline-basalt flows and of the analcite-bearing basic dykes of the Sydney district.

Coastal Dykes and Minor Sills.

These have been studied most thoroughly along the Illawarra Coast, and to a less extent in the Sydney district. The Illawarra dykes may be divided into those containing essential plagioclase and those in which this is absent or subordinate. The former comprise olivine-basalts and analcite- and nepheline-basanites, the latter monchiquites, analcite-basalts and nepheline-basalts. A few ophitic olivine-dolerites are also found.

The olivine-basalts are as a rule fine-grained and sometimes fluxional, and resemble the finer-grained rocks of the flows and necks, the augite being as a rule subordinate and more or less granular. In some of them, and probably in most, there is interstitial analcite, while a few contain nepheline. Some of the basalts are devoid of olivine. The non-felspathic rocks are very similar in thin section to the nepheline-basalts of the Blue Mountain area, being generally fine to very fine in grain, with microphenocrysts of olivine, while the augite is purple-brown,

TABLE VI.

| | I. | II. | III. | IV. |
|--------------------------------------|--------|--------|--------|--------|
| SiO ₂ | 41·86 | 44·61 | 45·25 | 47·56 |
| Al ₂ O ₃ | 14·40 | 20·01 | 15·13 | 15·20 |
| Fe ₂ O ₃ | 3·91 | 2·20 | 1·80 | 4·75 |
| FeO | 7·29 | 8·64 | 8·82 | 6·12 |
| MgO | 8·76 | 5·28 | 10·24 | 5·44 |
| CaO | 13·74 | 9·25 | 10·98 | 6·15 |
| Na ₂ O | 3·21 | 4·22 | 3·36 | 6·40 |
| K ₂ O | 0·91 | 1·80 | 1·22 | 2·32 |
| H ₂ O+ | 2·23 | 1·63 | 1·21 | 2·20 |
| H ₂ O- | 0·79 | 0·42 | 0·09 | 0·26 |
| CO ₂ | 0·02 | 0·08 | 0·06 | abs. |
| TiO ₂ | 2·30 | 1·55 | 1·52 | 2·40 |
| P ₂ O ₅ | 0·67 | 0·34 | 0·52 | 0·55 |
| MnO | 0·21 | 0·21 | 0·07 | 0·23 |
| FeS ₂ | — | — | — | 0·50 |
| etc. | 0·05 | 0·06 | 0·07 | — |
| | 100·35 | 100·30 | 100·34 | 100·07 |
| Sp. Gr. | 3·023 | 2·905 | 3·014 | |

| | I. | II. | III. | IV. |
|------------------|-------|-------|-------|-------|
| Orthoclase | 5·56 | 10·56 | 7·23 | 13·34 |
| Albite | 2·10 | 15·72 | 10·48 | 26·72 |
| Anorthite | 21·96 | 30·30 | 22·52 | 6·12 |
| Nepheline | 13·63 | 10·79 | 9·66 | 14·77 |
| Diopside | 33·30 | 7·08 | 22·68 | 16·62 |
| Olivine | 9·13 | 15·77 | 19·47 | 6·81 |
| Magnetite | 5·57 | 3·25 | 2·55 | 6·73 |
| Ilmenite | 4·41 | 2·89 | 2·89 | 4·56 |
| Apatite | 1·68 | 0·67 | 1·34 | 1·34 |
| Calcite | — | 1·80 | 0·10 | — |
| Pyrites | — | — | — | 0·50 |

I.—Nepheline-analcite-dolerite, (Limburgose, III.6".3.4"), Wharton's Mill, on road to Barrington Tops. Anal. W. G. Stone. *Ann. Rept. Dept. Mines N.S.W.*, 1926, p. 104.

II.—Dolerite, (Salemose, II".6".3.4), Mt. Warrawalong. *Mem. Geol. Surv. N.S.W.*, Geol. 6, p. 93.

III.—Dolerite, (Limburgose, III.6.3.4), Mt. Midderula, Co. Phillip. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 6, p. 123.

IV.—Nepheline-basanite (Monchiquose, (II) III.6.(1)2.4), Square Top, Nundle. Anal. W. N. Benson. *Proc. Linn. Soc. N.S.W.*, 1913, 38, p. 706.

often elongated in habit and generally very abundant. The felspathoid, however, is mostly interstitial analcite, so that the rocks are monchiquitic for the most part. A feature of these rocks is the presence of a barkevikitic hornblende in needles, which is in some instances subordinate to the augite but generally is of equal importance. This hornblende is in some rocks clearly a magmatic derivative of the titanaugite, and where the hornblende is in small patches in an otherwise augitic rock the presence of much accompanying analcite suggests that a local concentration of mineralisers may have favoured its crystallisation rather than that of pyroxene. Some of these rocks recall the camptonites of Mull and the Orkneys in Scotland.

There are also a few analcinites or fourchites, nepheline-basalts and nephelinites.

Of the minor sills some are analcite-basanites or fine-grained analcite-olivine-dolerites, while others, like No. 2 and No. 3 sills at Rixon's Pass, incline to be monchiquitic. The Nebo sills, to the west of Wollongong, are of the nature of fourchites or analcinites, with barkevikite in addition to titanaugite. In the groundmass are felspar needles, apparently orthoclase for the most part.

Some of these rocks of the dykes and sills contain large crystals of brown hornblende, up to one inch in length.

The dykes and small sills so numerous in the Sydney area are chiefly fine-grained analcite-basanites, with occasional brown hornblende in addition to titanaugite. At Newcastle there are quite a number of dykes, one of which, near the bathing-beach, contains considerable barkevikite, while another farther north is of coarser grain and has more analcite but less hornblende, and is devoid of olivine.

The geographical distribution of these coastal dykes and sills is interesting. The monchiquites and other non-felspathic rocks described in the Southern Coalfield Memoir are all situated between Wollongong and Black Head, Gerringong, a distance of about 25 miles. Among the dykes in this area there are many felspathic ones, but no non-felspathic rocks have been recorded, to my knowledge, anywhere north of Wollongong, as far as Newcastle at all events. There are not sufficient analyses available to enable us to say whether there are great chemical differences between the felspathic and non-felspathic types, but it is not impossible that the differences in nomenclature merely indicate to a large extent variations in the conditions of crystallisation of the same magma.

Chemically the rocks are seen (Table VII) to be very low in silica and of varying degrees of alkalinity, the extreme being represented by one of the Rixon's Pass sills with 14·5% of normative nepheline, whilst the most basic rock analysed is that of a monchiquitic dyke at Kiama, with 39·35% of SiO_2 . Many of the rocks have been so carbonated that their norms cannot be calculated.

On the whole, though there are no very close chemical resemblances, the rocks of these coastal dykes seem to

comprise the various types represented in the flows, but there is perhaps a greater proportion among them of the rather extreme alkaline types.

TABLE VII.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|--------------------------------------|--------|--------|--------|--------|--------|----------------|--------|
| SiO ₂ | 45·60 | 43·54 | 43·48 | 42·10 | 41·72 | 39·35 | 39·90 |
| Al ₂ O ₃ | 11·62 | 15·61 | 16·53 | 15·68 | 16·87 | 11·60 | 17·78 |
| Fe ₂ O ₃ | 2·80 | 3·20 | 3·42 | 3·40 | 5·90 | 3·32 | abs. |
| FeO | 9·18 | 8·64 | 8·91 | 7·11 | 3·87 | 7·38 | 9·45 |
| MgO | 10·41 | 9·16 | 7·12 | 8·26 | 4·23 | 9·82 | 12·86 |
| CaO | 8·46 | 8·88 | 8·88 | 9·91 | 10·32 | 12·66 | 10·34 |
| Na ₂ O | 2·58 | 3·44 | 3·27 | 4·20 | 4·99 | 2·00 | 2·66 |
| K ₂ O | 1·88 | 2·10 | 2·31 | 1·47 | 2·73 | 1·77 | 1·34 |
| H ₂ O + | 3·32 | 2·56 | 2·69 | 4·69 | 3·67 | 3·82 | } 0·62 |
| H ₂ O - | 0·76 | 0·32 | 0·31 | 0·66 | 0·45 | 1·28 | |
| CO ₂ | 1·01 | 0·21 | 0·40 | 0·08 | 2·54 | 4·04 | — |
| TiO ₂ | 1·85 | 1·81 | 2·35 | 1·45 | 1·70 | 1·98 | 2·50 |
| P ₂ O ₅ | 0·41 | 0·40 | 0·44 | 1·12 | 0·85 | 0·64 | — |
| MnO | 0·14 | 0·26 | 0·15 | 0·14 | 0·15 | 0·21 | 0·06 |
| BaO | abs. | 0·24 | 0·02 | 0·07 | 0·13 | 0·08 | — |
| SO ₂ | abs. | 0·10 | 0·21 | 0·03 | abs. | abs. | — |
| S | — | abs. | — | abs. | abs. | 0·46 | — |
| etc. | 0·02 | 0·06 | 0·04 | 0·05 | 0·12 | 0·09 | — |
| Less O=S .. | 100·04 | 100·53 | 100·53 | 100·42 | 100·24 | 100·50 0·01 | — |
| | | | | | | 100·49 | — |
| Sp. Gr. .. | 2·933 | 2·953 | 2·941 | 2·799 | 2·732 | 2 915 | — |

| | I. | II. | III. | IV. | V. |
|-------------------|-------|-------|-------|------|-------|
| Orthoclase | 11·12 | 12·23 | 13·34 | 8·9 | 16·12 |
| Albite | 22·01 | 9·96 | 13·10 | 8·9 | 15·20 |
| Anorthite | 14·46 | 21·41 | 24·46 | 19·5 | 15·57 |
| Nepheline | — | 9·94 | 7·10 | 14·5 | 14·48 |
| Thenardite | — | 0·14 | 0·43 | — | — |
| Diopside | 14·98 | 15·23 | 11·71 | 18·5 | 11·27 |
| Hypersthene | 2·16 | — | — | — | — |
| Olivine | 20·31 | 18·88 | 15·99 | 14·3 | 3·78 |
| Magnetite | 4·18 | 4·64 | 4·87 | 4·9 | 8·12 |
| Ilmenite | 3·65 | 3·50 | 4·56 | 2·7 | 3·19 |
| Apatite | 1·01 | 1·01 | 1·01 | 2·7 | 2·02 |
| Calcite | 2·30 | 0·50 | 0·90 | — | 5·70 |

I.—Olivine-dolerite (Camptonose, III.5.3."4), Wallaya Sill, Minumurra River. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 342.

II.—Analcite-basanite (Limburgose, III."6.3.4), Luddenham Dyke, Sydney District. Anal. H. P. White. *Rec. Geol. Surv. N.S.W.*, 7, p. 230.

III.—Analcite-basanite (Camptonose, (II) III.5(6).3."4). Bondi Dyke. Anal. J. C. H. Mingaye. *Rec. Geol. Surv. N.S.W.*, 7, p. 230.

IV.—Monchiquite (Limburgose, III.6.3.4), No. 2 Sill, Rixon's Pass. Anal. W. G. Stone. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 348.

V.—Fourchite (Essexose, II(III).6.2".4), No. 2 Sill, Mt. Nebo. Anal. J. C. H. Mingaye. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 344.

VI.—Monchiquite, Dyke No. 38, Kiama. Anal. H. P. White. *Mem. Geol. Surv. N.S.W.*, Geol. 7, p. 360.

VII.—Brown Hornblende from South Coast Sill. *Mem. Geol. Surv. N.S.W.*, Geol. 6, p. 350.

Vesicle-fillings, etc.

From a number of the newer basalts zeolites of various kinds and other vesicle-fillings have been recorded. Anderson⁽⁵⁹⁾ found analcite, chabazite, mesolite and natrolite in the basalt of Ben Lomond in New England, and Hodge-Smith has described the same assemblage with the exception of natrolite from Kyogle,⁽⁶⁰⁾ and at Ardglen⁽⁶¹⁾ he discovered a little natrolite and apophyllite. Chabazite has been observed in the basalt of the Mittagong Range.

Quite a variety of deuteric minerals has been obtained from the vughs and cracks in the Prospect dolerite, including prehnite, analcite, calcite, natrolite and pectolite, also a zeolite allied to thomsonite.

All these assemblages are in keeping with the somewhat alkaline characters of the basic rocks, and so is the fact that some of the minerals like analcite and natrolite may fill an interstitial rôle in the basalts and dolerites and thus play the part of primary minerals.

Xenoliths and Xenocrysts.

From various basic flows and intrusions there have been described from time to time inclusions both of rocks and minerals, and fragments of similar types have been found in breccia-filled necks. Some of the xenoliths are clearly accidental, such as the gneisses described by

Benson from the Gerringong dyke and the basalts, *etc.*, of the Hornsby neck; but others are of plutonic rocks, and their affinities are not so clear. These are mainly of basic and ultrabasic types, such as gabbro, norite, anorthosite, troctolite, pyroxenite and peridotites of various kinds, and they have been noted in necks,⁽²⁰⁾ ⁽⁴⁹⁾ coastal dyes,⁽⁶⁾ ⁽⁶²⁾ flows⁽²¹⁾ and sills.⁽⁶⁾ Eclogite has been described from Bingara,⁽⁴⁸⁾ and garnets from dykes at Moruya.⁽⁵³⁾

Benson, discussing these xenoliths, came to the conclusion, by reasoning which is in places somewhat difficult to follow, that they were of the cognate type. Dr. Ida A. Brown, on the other hand, argued cogently that, while the basalts of the dykes and necks were distinctly alkaline in their affinities, the xenoliths were essentially calcic in character, and therefore could not be regarded as co-magmatic with the enclosing lava; she suggested that the ultrabasic rocks might be as old as late Devonian. Benson, however, had already pointed to the improbability of the existence of a great bathylith of basic and ultrabasic rocks underlying nearly the whole of eastern New South Wales, and had postulated the existence at depth of a number of small highly differentiated bodies in different places.

The origin of these inclusions is therefore still an open question, and there can be no great harm in hazarding another suggestion regarding it.

It is perhaps significant that the inclusions are found in rocks belonging to the newer series of intrusions and extrusions, and the same is true of similar occurrences in Victoria.⁽²⁷⁾ It has been shown that in Skye,⁽⁶³⁾ Mull⁽⁶⁴⁾ and elsewhere the igneous cycle during the course of which the alkaline plateau-basalts were poured out included as

later episodes the intrusion of calcic plutonic rocks ranging from granite to ultrabasic types. These were injected at local centres, and according to Harker their magma must have been somehow derived from the same original magma that gave rise to the plateau-lavas. In this sense these calcic and alkaline rocks are co-magmatic. Now if it be assumed that the igneous cycle with which the older and middle series of this State were connected included the injection in various places of differentiated calcic magma at depth, then it is quite natural to find fragments of the plutonic rocks torn off and brought up in the upwelling of the magma of the newer basic series. Whether under such circumstances the xenoliths should be called accidental or cognate is a somewhat nice point which need not be discussed here.

Card has described the finding of large crystals of brown hornblende in the coastal dykes,⁽⁶⁾ and has doubted whether these are xenocrysts rather than true phenocrysts. It is perhaps significant that the chemical analysis of one of these crystals is not unlike that of a monchiquite from one of the South Coast dykes (Table VII). In view of this and of the abundant presence of barkevikite in these dykes, it seems natural to consider that the large hornblende crystals represent intratelluric crystallisations from the alkaline basic magma, and are therefore to be regarded as phenocrysts.

The derivation of sapphire and corundum from the Tertiary basalts was emphasised by Curran.⁽¹³⁾ For the most part the stones occur in Pleistocene or Recent drifts and in Tertiary deep leads over a wide area, but particularly in New England. Curran found sapphire associated with magnetite in a matrix of fresh basalt (probably of the newer series) in the ranges between Inverell and Glen

Innes; he pointed out also that at Berrima pleonaste, which occurs as inclusions in the basalt, also accompanied the sapphire in the drifts. Porter mentions a similar occurrence near Inverell.⁽⁶⁵⁾ In an olivine-basalt from the Green Hills neck, Blue Mountain area, I have observed corundum, containing symmetrically-arranged inclusions of rutile (?), associated with magnetite and basic plagioclase of coarse grain. Corrosion of the minerals indicates that the aggregate is a xenolith.

These occurrences recall in some respects the aluminous xenoliths of Mull,⁽⁶⁴⁾ which Thomas considers to be due to the metamorphism of shale-inclusions in a basic magma.

Magmatic Relations of the Rocks.

Although the petrological and chemical data are by no means complete it is possible, tentatively at least, to draw some deductions from the facts recorded above regarding our Tertiary vulcanicity, taken in conjunction with those already discovered in the neighbouring States, and particularly in south-eastern Queensland.

Three main groups may be recognised among the basic lavas, the first two of which are known to be represented among the older, while all are present among the newer series. The first group, that of the calcic basalts, is distinguished from the second, the plateau-basalts, chiefly by relatively high silica and low magnesia and by an absence of normative nepheline, while normative olivine may or may not be present. With these rocks may be compared many of those Queensland lavas whose analyses are quoted by Richards. It will be noticed that magnesia is low in those rocks from which normative olivine is absent, but increases markedly in those which are undersaturated, and with the increase in normative olivine the rocks

approach the plateau-type, in which normative nepheline is present.

The hypersthene-molecule bulks largely in the pyroxene of the calcic basalts, a fact in harmony with the observation that in a number of the rocks the augite is weakly-coloured and has a low optic axial angle—that in fact it belongs to the enstatite-augites. In others of the analysed rocks there is little or no augite, and the normative quartz and pyroxene are contained in the glassy base. Unfortunately no analyses of the porphyritic basalts are available, but without doubt these should be included with the calcic basalts. These basalts all show quite close affinities with the rocks of the quartz-dolerite kindred, the “central magma-type” of the Mull Memoir and the “flood-basalts” of Gregory and Tyrrell.⁽⁶⁶⁾

The rocks of the second group correspond closely with the plateau-basalts as defined by Harker⁽⁶⁷⁾ and others. In these the silica percentage is decidedly lower than in those of the first group, and the magnesia much higher, features which are reflected normatively in the invariable presence of olivine and nepheline, the latter being represented in part by analcite in the mode.

Both of the above types differ from the normal plateau- and flood-basalts chiefly in having a rather higher percentage of alkalis, and particularly of potash.

The third group comprises the more extreme alkaline basic rocks, the nepheline-basalts, leucite-basalts, monchiquites, fourchites, *etc.*, occurring as flows, necks, sills and dykes. The nepheline-basalts and monchiquites grade through basanites into the plateau-basalts, but there are no direct connections between these and the leucite-basalts or the fourchites. All these rocks are characterised by very low silica and high magnesia, but apart from this

they vary quite considerably among themselves. The leucite-basalts show many resemblances, chemical and mineralogical, to the nepheline-basalts.

The older and newer basic intrusives are to be joined partly with the second and partly with the third group. None of them is devoid of felspar, and for the most part their connection with the plateau-basalts is clear, but chemically some of them closely approach certain of the nepheline-basalts and monchiquites.

If any of the intrusions of the quartz-dolerite kindred are Tertiary, they doubtless represent the intrusive expressions of the magma which gave rise to the calcic basalts of either the older or the newer basic series.

The alkaline rocks of the middle series are mostly intermediate and acid. Of these the rhyolites and trachytes have much in common chemically and mineralogically with the intrusive syenites, akerites and sölvsbergites. The tinguaites are really sub-basic, judged by their silica percentage, and are unusually high in soda; chemically they do not appear very closely allied to the other rocks of the middle series. The lavas are associated with basic rocks, like the anorthoclase-basalt of the Warrumbungles and the andesitic basalt of the Canoblas Mountains.

Lastly, there is the small group of the rhyolitic pitchstones associated with the newer basic lavas.

The association of all these different types in the field is too close to be fortuitous, and the occurrence of similar assemblages in other parts of the world makes it clear that the original magma from which the whole suite are derived is of widespread distribution in both space and time. Tyrrell considers the flood-basalt type to be the one of most general occurrence and greatest bulk, and by implication would seem to regard the plateau-type as

derivative. On the other hand, Thomas and Bailey regard the latter as the original magma-type, for Mull and Ardnarmurchan at least,⁽⁶⁴⁾ ⁽⁶⁸⁾ and the former as the derived one, and their conclusions are supported by Bowen. The researches of Washington,⁽⁶⁹⁾ Holmes, Tyrrell and others have shown that the flood-basalt type, with its concomitant quartz-dolerite intrusions, is widely distributed among the basalts of the Deccan, the Thulean region, the Palisadan region, *etc.*, while for the second of these regions the association of plateau-types with the flood-basalts has been proved in various places.

For eastern Australia it would appear that both types of basalt are present in both the older and newer series, but no very definite indications have been obtained as to which is the dominant type or which came before the other in sequence. In the absence of such evidence it is perhaps legitimate to assume, what has been demonstrated to be possible, that the plateau-magma was the original and the other the derivative.

Field-association and mineralogical evidence alike attest strongly that the nepheline-basalts were derived from the plateau-magma. Indeed an examination of the analyses of these rocks and of the calcic basalts reveals that in composition these two types are strongly contrasted in certain respects, and to some extent it would appear that the oversaturated calcic basalts and the nepheline-basalts represent opposite poles of differentiation of the somewhat alkaline plateau-basalt magma. By means of a variation-diagram it can be shown that with increase in silica from the alkaline to the calcic basalts there is a fairly steady decline in magnesia and a somewhat irregular decline in lime; soda remains fairly constant within limits, and potash shows a slight but

distinct rise, while alumina and the iron oxides are quite irregular. How such a differentiation could be brought about it is difficult to say. Bowen has demonstrated for Mull that the non-porphyrific central (flood-basalt) type of magma could arise from the plateau-type by the crystallisation and removal of olivine and basic plagioclase. An ultrabasic differentiate, however, according to Bowen,⁽⁷⁰⁾ could form from a basic magma only by the crystallisation, sinking and accumulation of olivine and augite crystals. This would imply that the ultrabasic rock never existed in the condition of a liquid magma capable of being erupted; to account for the appearance of such an ultrabasic rock as a flow it would be necessary to postulate:

- (1) that the ultrabasic mineral-aggregate on the floor of the magma chamber was remelted;
- (2) that circumstances existed in the magma-chamber which made possible the early crystallisation and removal, by sinking or floating, of the plagioclase felspar, leaving for eruption a residuum of alkaline ultrabasic magma; or
- (3) that some separation of a more alkaline and more basic fraction of fluid magma from the plateau-basalt magma was possible.

The manner of derivation of the leucite-basalts is shrouded in obscurity. The similarities in appearance between these rocks and the nepheline-basalts, and the presence in them of nepheline, indicate some community of origin, but the leucite plays a more important rôle in the leucite-basalts than the nepheline in the nepheline-basalts. The geographical isolation of the leucite-basalts is rather suggestive of the action of horizontally-acting forces producing differentiation.

The acid pitchstones are clearly the counterparts, both in composition and in mode of occurrence, of the pitchstones of Skye and Mull and Arran—the acid differentiates of the calcic basalt magma. The presence of occasional hypersthene phenocrysts in the rocks, and of hypersthene and diopside in the norms, also points in the same direction. There are, however, no known representatives here of the *inimorites* and *leidleites* of Mull, unless the dacites and pyroxene-andesites of Queensland take their place.

The alkaline acid and intermediate rocks are clearly from their relatively small volume derived rocks. Jevons and others for Prospect, and Raggatt and Whitworth for Savoy, have shown that associated with some of the basic intrusive sills there are co-magmatic syenites, whose magma was evidently concentrated from the basic magma, possibly through the agency of the mineralisers present in it. The syenites are quite close chemically and mineralogically to some of the larger independent intrusions and lava-flows, and this suggests that these may be the result of large-scale concentration from a basic magma. It is significant in this connection that in the undifferentiated sills, where a second or interstitial crystallisation has occurred, the residuum of magma has evidently had a composition rather similar to that of the syenites.

Associated with the alkaline lavas at the Warrumbungle Mountains and elsewhere there are rather alkaline andesites or basalts, evidently related to the more acid rocks, and perhaps representing the particular magma from which these were derived. This in its turn was probably a derivative of the plateau-magma.

The composition of the tinguaïtes is peculiar and rather baffling to explain.

The alkaline middle series of eruptions were most probably connected with the magma of the older basic series, since such derivative types would be more likely to appear late than early in the sequence. Further, it is noteworthy that the basic intrusives believed to be associated with the older basic lavas are analcitic and have syenitic differentiates; these facts would indicate that the magma was rich in mineralisers, and if the same was true of the main magma the concentration of alkaline differentiates from it would be favoured. As suggested earlier, some significance may attach to the occurrence in the trachyte-tuffs of the Warrumbungle Mountains, of leaves of *Cinnamomum*, the characteristic plant of the older deep leads.

It is true that Jensen notes that in the Nandewars erosion of the older dolerites preceded the effusion of the trachytes; nevertheless there is evidence of much greater denudation of the middle series antecedent to the outpouring of the newer basalts, and I am inclined on the whole to regard the middle series as derivative from the older basic magma.

It may be suggested, then, that the plateau-magma of the older basic series produced flows and teschenitic intrusives, and likewise differentiated so as to give rise to some calcic basalts, with perhaps cognate intrusions, and afterwards to acid and intermediate rocks of pronounced alkaline type. When, much later, the reservoir was replenished with plateau-magma, differentiation for some reason, perhaps connected with the supply of mineralisers, took a different course, so that, although calcic basalts were produced, no light differentiates were

concentrated as the latest phase, but only the more basic alkaline lavas and intrusions appeared. The coastal dykes and minor sills may have been closely connected with the main newer basic episode, or they may represent the expression of the differentiation of a further reservoir-filling of plateau-magma, which differentiated to give the great variety of types now forming these minor intrusions.

In this scheme the dolerite sill of Tillynambulan and perhaps some other dolerite intrusions may be the intrusive equivalents of the calcic basalts of either the older or the newer series.

It is remarkable that among the newer basalts of south-eastern Queensland and the northern part of New South Wales there should be such a relatively great apparent development of the calcic types, while further south the plateau-type seems to be predominant. The relative positions of these in a vertical sense is not definitely determined, but some of the highest elevations are of plateau-basalt with accompanying nepheline-basalts, and at the same time in the extreme north there are known to be plateau-basalt types below the calcic ones, as at Mt. Lindesay. These things might be interpreted to imply that in the north flows of undifferentiated plateau-magma were followed by outpourings of calcic basalt with some rhyolitic differentiate, and that subsequently there were further flows, both in the north and spreading southward almost to the confines of the State, of plateau-lava with some calcic basalt and feldspathoid-basalts. But really the data on this point are so scanty and the position has been so complicated by erosion that little more than speculation is at present possible.

Comparisons with the Tertiary Igneous Rocks of
Queensland, Victoria, and Tasmania.

Of the rocks described by Richards from Queensland there are only a few which can fairly be said to represent the pre-trachytic basic lavas, and these, although strongly violet-tinted augite is present in some of them, show no nepheline in their norms. The reason is to be found, in part at least, in the fact that owing to oxidation of the rocks the proportion of Fe_2O_3 to FeO is increased, and in the calculation of the norm silica is thereby made available for the formation of albite where really there should be nepheline.

The older basalts of Victoria belong to both calcic and plateau-types and are olivine-bearing, the augite being sometimes pale-coloured, sometimes violet-brown. Certain of the rocks are really augite-andesites, and tachylytes have been noted. The older basic series has not been definitely recognised in Tasmania. The presence of trachytes, sölvbergites and other intermediate alkaline types, however, seems to indicate that there must have been some older basic eruptions in Tasmania. Throughout the State there are great sills and laccoliths of dolerite, oversaturated and undersaturated, which belong to the quartz-dolerite kindred. These are usually assigned a Triassic age,⁽⁷¹⁾ but apparently only because they are intrusive into Triassic and older strata. It seems not impossible that they may really represent the calcic magma of the Tertiary older basic series, which here expressed itself intrusively rather than as surface-flows.

Jensen⁽⁷²⁾ has shown that the alkaline rocks of the middle series are closely related to those of Queensland, Victoria and Tasmania, and there are some indications that some of the associated basic rocks are likewise

similar, the anorthoclase-basalt of the Warrumbungle Mountains, for example, comparing well with the macedonite of Mt. Macedon, Victoria.

The newer basalts of northern New England continue across the border into Queensland, with their concomitant acid pitchstones, *etc.* Chemically most of the basic lavas analysed are calcic, and both the normative and modal pyroxenes suggest enstatite-augite, but members of the plateau-group are also present, as indicated by the presence in some of them of violet-tinted augite, and of occasional analcite as vesicle-fillings. It is possible that in this State there are representatives of the Queensland augite-andesites, but so far they have not been recognised. Many of the Queensland newer basalts, especially in the north, were probably erupted after the close of the Tertiary era.⁽²⁹⁾

The Victorian newer basalts are composed of both calcic and plateau-types. Grayson and Mahony divided the newer basalts of the Camperdown district into an earlier and a later series, the latter of which were poured out from small centres of eruption in Pleistocene to Recent times. It is interesting to note that the norms of the analysed earlier basalts show no nepheline, whilst those of the later basalts are nephelinic.

The widespread occurrence of anorthoclase-basalts in the older and newer basic series of Victoria has no parallel in New South Wales. The only rock at all comparable with these and with the anorthoclase-basalt of Queensland is the "trachytic basalt" of Mt. Molong.

Nothing much appears to be known of the detailed petrology or the chemical composition of the Tasmanian newer basalts. They are olivine-bearing, and their plateau-magma affinities are suggested by the association with

them in places of nepheline-basanites and other alkaline basic types. In Victoria records of felspathoid-basalts are scanty. Mahony⁽³²⁾ records an olivine-nephelinite, and mentions that analcite-olivine-basalts are abundant in South Gippsland; these rocks are doubtfully referred to the older basalts. The only record I have been able to find of a nepheline-basalt from Queensland is of one discovered by Dunstan in the Dawson River⁽⁷³⁾ district. Apart from an occurrence of doubtful age near Cooktown in Queensland, leucite-basalts have not been recorded anywhere in eastern Australia outside New South Wales.

The equivalents of the older basic intrusives of this State are found in the alkaline dolerites of Ipswich (Q.). Mahony records abundant crinanites and dolerites in South Gippsland (Vic.), but whether these are of the older or the newer series is not apparent. In Tasmania intrusions of trachydolerites and nephelinites are found;⁽⁷⁴⁾ a slide of the former which I have examined is almost identical with the olivine-dolerite of Gragin Peak, near Warialda, N.S.W., belonging probably to the newer basic intrusive series.

There is not sufficient information available to enable one to say whether the coastal dyke-system of New South Wales has its counterpart in the other States.

It would appear from the foregoing that in spite of certain differences there are general petrological similarities throughout the rocks of eastern Australia, and it is fairly evident that the same original magma underlay the whole area, while the course of differentiation was in general similar from place to place. Eastern Australia can therefore be regarded as a great petrographical region of dominantly basic type in Tertiary and post-Tertiary time, originally comparable in area with other

great basaltic regions of the world. This region may be divisible into a number of petrographical provinces. In point of complexity and range of petrological types represented it possibly surpasses most of the other similar regions; in particular there seems to be an unusually great development, especially in New South Wales, of alkaline intermediate and acid rocks and of the more extreme basic and ultrabasic alkaline types.

Manner of Extrusion of the Basic Lavas.

The evidence available does not permit of a definite pronouncement on this matter. It is usually contended that the general absence of fragmental material and the sparse distribution of central vents point to fissure-eruptions, but such a contention is in the nature of the case always difficult to prove.

Wearne and Woolnough⁽⁷⁵⁾ found two large dykes in the Main Range, near Toowoomba, 600 and 200 yards wide respectively, which are probably the largest yet recorded from eastern Australia, and which would be capable of supplying lava for large flows.

Richards considers that while some of the pre-trachyte basic eruptions were explosive and from central vents, the newer basic lavas welled up from fissures. In New South Wales the linear disposition of some of the masses of basalt, as in the Mt. Royal Range, and the Liverpool Range with its eastward continuation, taken in conjunction with the great thickness of the lava along these lines and its thinning away from them, almost inevitably suggests great fissure-eruptions, or extrusions from a series of centres along lines of weakness; but of course the present arrangement is in part due to post-basaltic erosion.

Andrews has noted the absence of volcanic vents in the newer basic series of the New England area, and Harper has commented on a similar absence in the Illawarra area and adjoining highlands. No central vents have with certainty been recognised on the Southern Highlands. On the other hand, there have been found upwards of one hundred necks in various places. The positions of most of these are plotted on the map (Fig. 6), and it will be seen that there is a tendency for them to be concentrated in certain areas, though this may be partly an illusion due to incomplete survey. It may be pointed out that most of the necks are within, or around the margin of, the area of Permian and Triassic subsidence and sedimentation, and it is perhaps noteworthy that in every case where the lava-filling has been examined it has proved to be plateau-lava or else basanite, nepheline-basalt or monchiquite. There is some evidence that parts of these Triassic areas were regions of sagging at times during the Tertiary Era, and it may well be that where fairly uniform subsidence occurred, unaccompanied by actual dislocation of the massive horizontally-bedded strata, fissure-eruption on a regional scale was discouraged and instead there were sill-intrusions and scanty outpourings of lava through central vents. A parallel might be drawn between these centres of eruption, with their rather alkaline basic lava, and those formed along the coast of Fifeshire during the crustal sagging and volcanic activity which took place in Scotland in Permian time.⁽⁶⁷⁾

Tectonics.

When we come to consider the nature of the earth-movements attending the eruption of the Tertiary magmas in eastern Australia we are faced with a certain lack of pertinent data, largely due to the fact that except in the

Miocene-Pliocene "Murray Gulf" extending from Victoria and South Australia up the valleys of the Murray and Darling Rivers almost to Broken Hill there was no marine sedimentation. Sir Edgeworth David⁽³⁸⁾ has testified that "the palæogeography of Australia from the close of Santonian time down to the present is bristling with difficulties".

The important fact must be borne in mind that, if the leucite-basalts be excepted, the eruptions were confined to a crescentic belt along the east coast 250 miles wide and convex to the east, that is, to the region which was subject to vertical movements right to the end of the Tertiary era. That this correspondence is more than a coincidence seems almost axiomatic.

Andrews⁽⁷⁷⁾ has pointed out that sections taken in various places from the coast across the main divide to the western plains show profiles which have in general the shape of a flat arch, a state of affairs due mainly, no doubt, to the late-Pliocene Kosciusko uplift, but also to movements during earlier parts of the Tertiary Era as well.

According to David,⁽³⁸⁾ the early Tertiary Australia was a nearly perfect peneplain. By the time the older basalts were being erupted, however, a certain degree of relief had been produced by uplift and erosion in parts of New South Wales, since the flows of Emmaville, Tingha and Kiandra occupy old valleys of quite considerable depth. The nature of the material composing the deep leads suggests that prior to the effusion of the lavas there had been sinking of the surface, and certainly in Victoria during the eruption of the older basic series subsidence sufficient to permit ingression of the sea took place.

The strata associated with the Nandewar laccolith and the Mt. Jellore Essexite sill were contemporaneously tilted, and Raggatt⁽⁷⁶⁾ has shown that the phacolithic basic intrusions of the Muswellbrook-Singleton district were injected in connection with movements producing open folding. It would appear therefore that tangential forces operated during the injection of the older basic intrusives.

The existence of a thick cover of laterite to the New England basalts might be taken to indicate that following the extrusion of the lava conditions of stillstand or slow subsidence prevailed there over a long period, during which erosion was negligible and deep chemical weathering was active. On the other hand, the occurrence of the ridges of older basalt, as at Kiandra and Cooma, well above the newer basalt, and the existence of monadnocks of the older intrusives, as at Mts. Bocobel and Dangar, would indicate that there must have been elevation and considerable erosion between the times of eruption of older and newer basalts.

In some parts at all events of the affected area two distinct epochs of uplift separated the older and newer basalts, for below the level of the older monadnocks there is a well-developed peneplain level out of which mature valleys had been carved before the newer basalts were poured over the landscape.* The first of these uplifts may have preceded the extrusion of the middle series, but the second certainly succeeded it. Quite considerable topographical relief characterised the surface on which the newer basalts were laid down in some parts of the

* For example, the basalts of Gulgong in part occupy the floor of the valley of the Cudgegong River, which in its turn is cut into the old peneplain on which Mts. Bocobel, Carcalong and Boiga stand as residuals (see Fig. 2).

region at least, and Andrews⁽⁷⁷⁾ has pointed out that many of the valleys, though of youthful type, contain thick deposits of gravel, sand, clay and lignite under the lava, indicating that subsidence had set in prior to the volcanic outbursts.

Doubtless the various movements of uplift and subsidence were to some extent differential, and quite probably planes of dislocation developed which afforded channels for the upward passage of magma, but if so the traces of these channels have been largely obliterated.

There may have been subsidence in some places following the extrusion of the newer lavas, but on the whole after imperfect peneplanation the subsequent movements were in the nature of uplift of a differential nature and on a considerable scale. The only downward movement of any magnitude was that which caused the foundering of a coastal strip and the formation of the continental shelf.

All these later movements were separated by very long intervals of time from even the latest of the eruptive episodes, and it is difficult to believe that there could be any causal relation between them. Where movement and vulcanism are connected we should expect a certain degree of contemporaneity, but as a matter of fact there have been no signs of vulcanism attending the foundering of the coastal areas or the formation of any of the known late-Tertiary or Pleistocene or recent faults and flexures. Perhaps the eruptions are yet to come!

The net result of all the earth-movements during Tertiary time was an elevation, culminating at varying distances west from the present coast-line and decreasing in value from the central axis to east and west.

While, then, the Tertiary eruptions were very probably connected intimately with downward movement and subsidiary folding, they can also be regarded as being associated broadly with a great effort of uplift which commenced after the Cretaceous period and did not achieve its culmination till the close of the Tertiary Era. The reasons for this uplift are rather outside the scope of this address, but it may have been not unconnected with the prolonged sinking of the Tertiary "Murray Gulf", and with a possible sagging of what are now the Western Plains, to say nothing of the thrusts from the Pacific and the Tasman Sea which, according to Sir Edgeworth David, affect eastern Australia to the present day.

GENERAL SUMMARY.

Volcanic activity during the Mesozoic Era was not extensive in the areas of sedimentation in New South Wales, being confined, so far as we know, to explosive activity during the early Triassic, and eruptions of basic lava during the Jurassic periods.

A few hypabyssal intrusions of uncertain age are known, and an intrusion of granite in northern New England may be of late-Cretaceous age.

During the Tertiary Era there were eruptions predominantly basic on a regional scale along a wide coastal belt. Two main groups of eruptions are recognised:

- (1) an older, consisting of flows and hypabyssal intrusions of basic magma followed by flows and intrusions mainly of alkaline intermediate character; and
- (2) a newer, composed of basic flows and intrusions with a few acid lavas, followed by a series of basic dykes and minor sill-intrusions.

Petrologically the basic lavas comprise calcic and plateau-basalts with minor amounts of more alkaline basic and ultrabasic types. The older basic intrusions are teschenitic and the newer theralitic, while some sills and dykes of the quartz-dolerite kindred may be the intrusive equivalents of the calcic basalts.

The whole series is obviously co-magmatic with the Tertiary igneous rocks of Queensland, Victoria and Tasmania, and shows petrological resemblances to the rocks of the Thulean and other basaltic regions of the world. The eruptions were closely connected with vertical crustal movements in what are now the highland and coastal regions.

CONCLUSION.

It cannot be too strongly emphasised that there are still many gaps in our knowledge of post-Palæozoic igneous activity, and that any conclusions or generalisations can therefore only be regarded as tentative, and may require drastic revision later on.

Nevertheless it is hoped that this account, full of shortcomings as it is, may serve to direct greater attention to some important and fascinating aspects of our geological history. An intensive field- and laboratory-study, particularly of the Tertiary igneous activity, is highly desirable, both because of its intrinsic interest, and because of the light that it may throw not merely on questions of petrology but also on problems connected with Tertiary stratigraphy, tectonic history and palæogeography, as well as with out present day physiography.

In this as in other geological investigations every advance along the path of knowledge opens up almost

endless vistas of new problems that lie ahead; for, like his fellow-scientists, the geologist can say with that doughty explorer of the unknown, Ulysses:

"all experience is an arch wherethro'
Gleams that untravell'd world whose margin fades
For ever and for ever when I move."

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THE DECOMPOSITION OF CHLOROFORM BY RADIATIONS FROM RADON.¹

By G. HARKER, D.Sc.

(With one text-figure.)

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At the suggestion of the Director of Cancer Research, an investigation has been carried out on the effect of radon on the decomposition of chloroform in which various metal filters have been employed. As is well known, light decomposes chloroform with liberation of chlorine, which gradually forms hydrochloric acid, and radiations from radon have a similar effect. The decomposition was followed by measuring the chlorine set free by titration with potassium iodide and N/1,000 sodium thiosulphate using starch as indicator. Two varieties of chloroform were used in the course of the work, *viz.*, Schering's and Mercks' both very highly purified. Consistent results were obtained from each variety, but, as will be mentioned later, the decomposition effected by a given amount of radiation acting upon an equal volume of each variety was by no means the same.

One of the objects of the work was the determination of the decomposition produced by a definite quantity of γ radiation, in order to effect a comparison with that

¹ This work was carried out under the control of the Cancer Research Committee of the University of Sydney and with the aid of the Cancer Research and Treatment Fund.

produced by a given quantity of X-radiation. Data are available for the energy of the γ radiation emitted per unit of time from a curie of radon. Hence with a known quantity of radon as source, by measuring the fraction of γ radiation absorbed in passing through a given quantity of chloroform, together with the decomposition produced, the latter can be correlated with the γ radiation expressed in terms of energy.

Effect of Metal Filters.

The main investigation was concerned with the effect on the decomposition produced by interposing various metal filters between the radon and the chloroform. The experiments were carried out in cylindrical vessels with the radon seed placed centrally, and vessels of various diameters were used in order to measure the effect of the radiations through different thicknesses of chloroform. The seed placed centrally in a vertical position was covered above and below by the chloroform to a depth of approximately 1 cm. The same quantity of chloroform was used for any particular type of vessel, so that the conditions were the same in any set of tests with metal filters, the radiations having to pass through the same quantity and thickness of chloroform. Evidently not much of the total radiation proceeds in the direction of the axis of the seed, as the amount of decomposition was little influenced by increasing the amount of chloroform in this direction, at any rate in the smaller cylinders. The amount of γ radiation absorbed by the various metal filters and by different thicknesses of chloroform was measured by the electroscope (provided with lead walls 6 mm. thick) and is given in Table I.

The radon was contained in a glass seed about 1.8 cm. in length and about 1.8 mm. external diameter.
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Metal cases of aluminium, copper and lead 1 mm. in wall thickness, 2 mm. in internal diameter, and 3 cm. in length were provided, into which the radon seeds would fit: also a lead case of the same length and internal diameter but with walls 3 mm. thick. For platinum an empty case with walls 0.5 mm. thick was used, but as the internal diameter of this case was considerably less than 2 mm., smaller seeds had to be prepared for it.

TABLE I.—*Percentage Reduction in γ -Radiation from Radon as Shown by the Electroscop.*

| Material. | Thickness in mm. | Percentage Reduction. |
|--------------------|---------------------|--------------------------|
| Chloroform | 4.0 | 2.0 |
| | 9.3 | 4.0 |
| | 21.5 | 9.7 |
| Glass | 1.0 | 0.80 |
| Aluminium | 1.0 | 0.73 |
| Copper | 1.0 | 2.55 |
| Lead | 1.0 | 5.3 |
| Lead | 3.0 | 15.2 |
| Platinum | 0.5 | 6.5 |
| Platinum | 0.5 | 7.5 |
| | | } Different cases. |

The seed, either free or in its metal case, except the large lead case, was slipped inside a glass tube of about 6.3 mm. external diameter and 1 mm. wall thickness. This tube passed through a cork which held it in position in the cylindrical vessel. Chloroform could not be brought into direct contact with the walls of the metal cases because the free chlorine liberated rapidly attacks the metal. The glass tube served the double purpose of preventing the contact of the metal with the chloroform, whilst ensuring that the thickness of chloroform was uniform for experiments both with the radon seed alone and with the metal screens. The free chlorine liberated

by the action of the radiation also reacts slowly with the chloroform itself, so that after removal of the radon the amount of chlorine gradually decreases. This alone would prevent the chlorine produced by the radon being strictly proportional to the time of its action, but the proportionality is much further reduced by another factor. Chloroform which has been subjected to the action of radon, and which therefore contains chlorine, hydrochloric acid and other secondary products, when subjected to the further action of radon, produces an additional amount of chlorine which is definitely less than would be produced from the same amount of fresh chloroform. This action of the radiation, when found, explained some discrepancies in the results which at first were a little puzzling. The modified action of the radiation in the presence of secondary products was much more important in producing decrease of free chlorine than the direct action of chlorine already referred to. The net result was that in an experiment lasting one hour the chlorine actually determined was approximately 10 per cent. less than it would have been had no secondary reactions taken place. A correction could be applied where the test lasted longer than one hour, but in practically all the experiments the chloroform was subjected to the action of the radon for a one-hour period and all results are stated for this term, uncorrected for the loss of chlorine taking place during the period. The radon was generally drawn off every week and except in the case of the small seeds for the platinum cases, was usually from 200 to 250 millicuries in strength when first prepared.

The internal diameters of the three cylindrical vessels employed were 1.45, 2.47 and 4.93 cm. respectively, and

the external diameters of the central glass tube carrying the radon 0.65, 0.61 and 0.63 cm., so that the radiations from the radon passed through thicknesses of chloroform which were 0.40, 0.93 and 2.15 cm. in each case. The quantities of chloroform used were 6.5 cc., 30 cc. and 65 cc. respectively. With 30 cc. in the medium sized cylinder the seed was covered to a depth above and below of about 2 cm., but it was found that there was little difference in the amount of decomposition when the volume was reduced to 20 cc., leaving only 1 cm. of liquid above and below. The results obtained by using different filters are shown in Tables II and III.

TABLE II.—*Decomposition of Chloroform Through Different Filters.*

Expressed in cc. N/1,000 thiosulphate on the basis of 100 millicuries of radon before filtration.

| Metal Filter. | Distance Travelled by Rays through Chloroform. | | |
|-------------------|--|----------|----------|
| | 0.4 cm. | 0.93 cm. | 2.15 cm. |
| Absent | 0.53 | 0.71 | 0.90 |
| 1 mm. Al. | 0.26 | 0.46 | 0.62 |
| 1 mm. Cu. | 0.14 | 0.33 | 0.53 |
| 1 mm. Pb. | 0.135 | 0.30 | 0.51 |
| 0.5 mm. Pt. | 0.125 | 0.287 | 0.54 |

3 mm. Pb. gave 0.18 for 0.71 cm. and 0.40 for 1.94 cm.

With the largest cylinder the depth of chloroform was hardly sufficient to ensure a path of 2.15 cm. for all the radiation and the figures obtained with this vessel are low in consequence. In most cases the figures given represent the mean of a number of experiments with different radon strengths. The radon strength varied

considerably, *viz.*, from 93 to 255 millicuries in all tests except those with the platinum filter where, using a smaller seed, the variation was from 62 to 93 millicuries. The radon value was determined on the day following its preparation and its strength in subsequent experiments

TABLE III.—*Decomposition of Chloroform Through Different Filters.*

Expressed in cc. N/1,000 thiosulphate on the basis of 100 millicuries of radon reckoned after filtration through metal and allowing also for absorption in the chloroform passed through, *i.e.*, decomposition per actual 100 millicuries per hour.

| Metal Filter. | Distance Travelled by Rays through Chloroform. | | | Average Decomposition for 0.4 cm. Absorption between the distances— | |
|-------------------|--|----------|----------|---|-----------|
| | 0.4 cm. | 0.93 cm. | 2.15 cm. | 0.4-0.93 | 0.93-2.15 |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Absent | 0.53 | 0.73 | 0.96 | 0.159 | 0.075 |
| 1 mm. Al. | 0.265 | 0.48 | 0.67 | 0.162 | 0.063 |
| 1 mm. Cu. | 0.145 | 0.348 | 0.58 | 0.153 | 0.076 |
| 1 mm. Pb. | 0.143 | 0.325 | 0.57 | 0.137 | 0.082 |
| 0.5 mm. Pt. | 0.132 | 0.31 | 0.60 | 0.134 | 0.097 |

3 mm. Pb. for average decomposition over 0.4 cm. between 0.71 cm. (0.217) and 1.94 cm. (0.504)=0.094.

was obtained by calculation from the elapsed time. The decomposition for the same period of time through the same thickness of chloroform was found to be closely proportionate to radon strength. The action of the radiation was measured by titrating the chlorine set free from the chloroform with N/1,000 sodium thiosulphate. For simplicity in comparison the results in Tables II and III are stated as cc. N/1,000 thiosulphate solution

required to titrate the liberated chlorine on the basis of 100 millicuries of radon for one hour. Some of the radiation from the radon is absorbed by the glass and metal filters and some by the chloroform as shown in Table I. Table II gives the decomposition figures with 100 millicuries radon at the source (in the seed), whilst in Table III a correction has been applied for the passage of the radiation through the metal filter and through half the thickness of the chloroform, giving therefore the decomposition per 100 millicuries in an hour as delivered to the chloroform. In addition the average decomposition over a distance of 0.4 cm. is given between the distances of 0.4 to 0.93 and 0.93 to 2.15 cm., columns 5 and 6, in order to compare these figures with those in column 2.

Glancing at Table III it is seen that the decomposition produced by the unfiltered radiation for the first 0.4 cm. distance is very much greater than the filtered, but that it rapidly falls away in value as the distance increases. Filtration through only 1 mm. of aluminium reduces the decomposition in the first 0.4 cm. to half, whilst in the succeeding 0.53 cm. it is practically the same as for the unfiltered. By the interposition of 1 mm. copper in place of aluminium a further large reduction in the decomposition over the first 0.4 cm. takes place. The substitution of heavier metal filters, *viz.*, lead and platinum for copper, produces only a small further reduction. Turning to column 5, which gives the decomposition for the next 0.53 cm. expressed in terms of 0.4 cm., the figures for all filters are much more alike than for column 2 and show a far more gradual falling off with the heavier filtration. Column 6 expresses the average decomposition for 0.4 cm. between the distances 0.93 and 2.15 cm., and here a reversal takes place, the figures increasing in value with

the heavier filters, the only exception being aluminium. However, the figures given in Table II for aluminium for the distances 0.93 and 2.15 cm. rest upon a single observation in each case. It was thought that the reversal in the order of the figures shown in column 6 might be accounted for by secondary radiation from the glass and metal filters. Secondary radiation from glass would be softer and more rapidly absorbed than that from the heavier metals, hence, assuming it to have an effect upon decomposition, secondary radiation from the glass would give rise to an increased amount near the glass whilst that from the metals would penetrate further. The figures in column 6 are obtained by difference from those in columns 3 and 4, and it was considered advisable to test directly the effect of the radiation upon the outer layer of chloroform. For this purpose a modified apparatus was devised as shown.

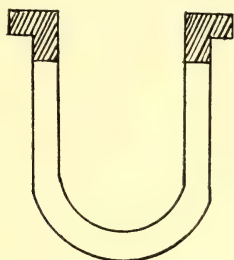


Figure 1.

Two large test tubes were obtained with different diameters. The larger had an internal diameter of 4.87 cm. and the smaller, with an external diameter of 4.23 cm., was kept centrally inside the larger by means of a wooden sleeve. An intermediate space of 0.32 cm. in thickness was thus provided. The inner test tube and the intermediate space contained chloroform and the

radon seed, either by itself or in its metal case, was placed in a glass tube. This glass tube was held centrally in the inner test tube by means of a cork. The amount of decomposition taking place in the outer 0.32 cm. of chloroform was determined and calculated to 0.4 cm. With a reduced thickness of chloroform (0.32 cm.) and considerable absorption of the radiation before entering the outer layer the amount of chlorine liberated was smaller than usual. After making the estimations of chlorine, careful blank tests were carried out to find the corrections necessary in determining these small amounts. On applying these corrections and allowing for loss of radiation by absorption, it was found that the figures for decomposition in the outer layer were all so close as to be practically identical, the average being 0.122 for 100 millicuries in an hour. This figure is considerably greater than any shown in column 6, Table III, and it appeared as though the passage of the radiation through glass before entering the outer layer might have an enhancing effect. To test this a suggestion made by Professor Vonwiller was followed. If secondary radiation from glass was contributing to the decomposition its effect should be more marked in a thinner layer of chloroform. Accordingly two test tubes were chosen with an intermediate space 0.16 cm. thick. The figure for decomposition obtained when calculated to 100 millicuries was exactly half that obtained in the 0.32 cm. layer, showing no evidence of effects from secondary radiation from glass. Further, to test the point silica and porcelain tubes were selected to hold the radon and glass tubes chosen of the same diameter and adsorption power for radiation. The radiations from these tubes were passed through equal thicknesses of chloroform. The results

were identical, again showing no evidence of any differentiation caused by secondary radiation.

Effect of Secondary Products on the Decomposition.

In the absence of this evidence the question arose whether the divergence in the figures for the outer layer was not due to the effect of the products formed on the further decomposition of the chloroform. The amount of chlorine (and other secondary products) is always greater where the radiation is unfiltered or lightly filtered. If these secondary products exert a detrimental effect on the formation of further chlorine it would explain why the values, shown in column 6, Table III, for the unfiltered and lightly filtered radiations are lower than for the heavily filtered. To test the effect of secondary products, experiments were carried out whereby chloroform previously exposed to radon and containing a known content of chlorine (treated chloroform) was again exposed and the additional amount of decomposition compared with that given under the same conditions by a sample of stock chloroform. Some of the results are shown in Table IV. The first experiments were made in the medium sized cylinder into which 20 cc. of treated or stock chloroform were placed. The radon seed was placed in the 3 mm. lead case and this was placed in a glass tube inserted in a larger glass tube, leaving a thickness of 0.4 cm. of chloroform between the outer wall of the larger glass tube and the inner wall of the cylinder. The treated chloroform was formed by acting upon some stock material overnight with radon and was diluted to any required degree with liquid from the stock. The treated liquid slowly diminishes in chlorine content and it was titrated at intervals, the values assigned to it in column 3, Table IV, representing

its chlorine content at the time the determinations were made of the radiated material, column 4.

TABLE IV.—*Radiation of Treated Chloroform.*

| Radon Strength in m.c. | Metal Case. | Titration Treated Chloroform before Radiation. | Titration Treated Chloroform after Radiation. | Gain. | Titration Stock Chloroform after Radiation. | Difference in effect on Stock and Treated Chloroform |
|------------------------|-------------|--|---|-------|---|--|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 188·8 | Pb. 3 mm. | 0·73 | 0·85 | 0·12 | 0·21 | 0·09 |
| 186·0 | " | 0·68 | 0·78 | 0·10 | 0·20 | 0·10 |
| 82·4 | " | 0·48 | 0·54 | 0·06 | 0·10 | 0·04 |
| 138·4 | Cu. 1 mm. | 1·27 | 1·33 | 0·06 | 0·11 | 0·05 |
| 215·8 | Al. 1 mm. | 1·65 | 1·95 | 0·30 | 0·39 | 0·09 |
| 180·1 | Cu. 1 mm. | 1·36 | 1·46 | 0·10 | 0·14 | 0·04 |
| 178·0 | Al. 1 mm. | 1·32 | 1·58 | 0·26 | 0·32 | 0·06 |

The experiments with copper and aluminium were carried out in different vessels to those with lead, but all clearly show that the presence of secondary products diminishes the production of chlorine. Variations in the amounts of these products provides in some degree the explanation for the anomalies found in column 6, Table III.

In obtaining the values shown in Tables III and IV for 2·15 cm. distance the desire to cut down the quantity of chloroform in the large cylinder as much as possible, both for the purpose of titrating its chlorine content and also from motives of economy, led to low values being obtained, as the total depth of liquid, *viz.*, 4 cm., was insufficient. In the experiments in which the decomposition in the outer layer was obtained directly in the space between two test tubes, the depth of liquid was 7 cm. The radiation was heavily filtered in all these experiments before entering the outer layer, and the figure obtained, 0·122 per 100 millicuries, agrees well with the figure 0·121 obtained from the value given for

0.71 cm. using a 3 mm. lead filter ($\frac{0.217 \times 0.4}{0.71}$) where the radiation was filtered to somewhat the same extent and the depth of liquid adequate.

The action of the secondary products provides another analogy between photochemical and radiation phenomena. The effect of added materials has been studied in photochemical reactions and it has been shown that in several instances the action of light is greatly influenced by these added substances. In some cases the decomposing effect of light is increased, in others diminished. The generally accepted explanation is that the added substance aids or hinders the action of light by activating or deactivating the molecule to be decomposed. It is now evident that decomposition by γ radiation may be similarly influenced by the presence of impurities. It is clear that in the present instance an alternative explanation to the deactivation of the chloroform molecule by secondary products is that the radiation activates the chlorine and causes it to combine more readily with unchanged chloroform. But whatever the exact explanation for the loss of chlorine, there is no doubt regarding the marked effect of a minute trace of secondary products. Taking the average of the first two experiments in Table IV, it is found that the presence of 0.0001 gram in 100 grams, *i.e.*, one-ten thousandth per cent. of chlorine, or its equivalent in hydrochloric acid or other secondary compounds, lowered the additional formation of chlorine in one hour's radiation to nearly half. It might be thought that this points to recombination of chlorine as the explanation of the action of the radiation, but that this is not necessarily the case is shown by other evidence. Mention has been made of the fact that the two varieties of stock chloroform used, *viz.*, Schering's

and Mercks', both gave consistent results, but that the amount of decomposition for each varied. Under precisely the same conditions of experiment the figures can be thus represented in terms of c.c. thiosulphate per 100 millicuries in an hour.

TABLE V.—*Radiation of Schering's and Mercks' Chloroform.*

| | Distance. | Schering. | Merck. |
|---------------------------|-----------|-----------|--------|
| Glass 1 mm. | 0.4 | 0.53 | 0.44 |
| Al. 1 mm. | 0.4 | 0.26 | 0.20 |
| Pb. 3 mm. | 0.71 | 0.18 | 0.12 |

The difference between them is about 17 per cent. for unfiltered radiation and about 33 per cent. for heavily filtered. Neither variety of chloroform contained a trace of chlorine, although a minute trace of this could be readily detected, and it would appear that the presence of some other substance than chlorine is responsible for the marked difference in response to radiation.

The results obtained with treated chloroform and with Schering's and Mercks' varieties stress the important part played by traces of impurities in the effects of radiation. In a previous article,⁽¹⁾ in which the action of radiation on living tissue was compared with the production of an image from a photographic film, attention was drawn to the recent discovery of the part played by minute traces of impurities in the gelatine of a photographic film. The following quotation from this article may be of interest:

"It has long been known that silver halides possess increased sensitivity to light in presence of gelatine, and it was also known that different brands or even different batches of gelatine differed greatly in sensitizing power. It was found that the sensitivity was not due to any ordinary known constituents of gelatine, but to the presence of minute accidental amounts of

organic isothiocyanates, compounds containing sulphur. Probably the sensitizing substance present in most samples of gelatine is allyl isothiocyanate, $C_3H_5N:C.S.$ This substance reacts with the surface of the silver halide grains, forming local patches of silver sulphide. In the neighbourhood of these patches the stability of the silver halide is reduced, so that light produces decomposition more readily than elsewhere, thus starting a centre of reduced silver atoms which is developable by the usual developers. The proportion of sulphur-containing compound in the gelatine is about one part in 300,000: much more than this produces fog, the silver halide grains being rendered too unstable."

It is evident that what may apply in the case of the action of light may also apply with X and γ radiation and that the course of the action may be greatly altered by mere traces of certain impurities. This means for one thing that the variations in the radio-sensitivity of tissues may be due to the presence or absence of traces of certain substances, and further, that by causing the tissues to absorb such substances or others like them in only minute quantities, the radio-sensitivity may be profoundly modified.

In therapeutic practice with radiation it has been found advisable to avoid, as far as possible, radiating tissue in contact with bone or cartilage as inflammation of the tissue is often set up. This inflammation is generally regarded as being caused by soft secondary radiation from the bone or cartilage. Although no evidence had been obtained so far of any decomposition of chloroform through secondary radiation, the metal cases containing the radon had always been enclosed in a glass tube and much of the radiation would be absorbed by the glass. An attempt was therefore made to cover the metal with a thin film of some substance which would prevent chlorine acting upon the surface of the metal and yet be thin enough to allow secondary radiation through. After some tests with various sub-

stances collodion was found suitable. The metal cases were dipped in collodion solution and on drying, a thin adhesive film remained. Blank tests showed that this surface was only slightly affected by chlorine. Many tests were made in which the coated metal cases containing the radon were suspended in the chloroform, being held in a small basket made of glass filaments. As was to be expected, in the absence of the extra filtration due to glass, these tests accentuated the difference between the aluminium filter and those of copper and lead, but there was no evidence of an increase in decomposition due to secondary radiation. The fact that a particular compound chloroform does not appear to be influenced by secondary radiation is no proof that a composite substance like tissue would not react to it.

It has been seen that very heavy filtration, *e.g.*, with 3 mm. lead, left a radiation which effected much the same decomposition per unit distance whether adjacent to or removed by 2 cm. from the filter whereas the unfiltered or lightly filtered radiation gave a heavy decomposition near the radon seed which rapidly fell off in value. The radiation producing this excess decomposition had little penetrating power and was considered as either very soft γ or highly penetrating β radiation. Ordinary β radiation would be easily absorbed by the 1 mm. walls of the glass tube used to hold the radon seed.

β Radiation.

Dr. Colwell⁽²⁾ has recently shown that the β radiation from radon has reducing properties. Experiments with radon contained in very thin-walled glass vessels showed that solutions of several dyes methylene blue, brilliant green, fuchsin were decolorised and that Fehling's solution, alkaline permanganate and ammoniacal silver

nitrate were reduced. He points out that the actions of X-rays and of the penetrating rays from radium are generally considered as oxidising in character. Some of Dr. Colwell's experiments were repeated in order to determine whether there was any difference chemically between the easily absorbed and the penetrating radiation from radon. The radon seed as before either alone or in its metal case was placed in a central glass tube and surrounded with the solution of a dye or of ammoniacal silver nitrate. It was found that the radiation with reducing effect could easily penetrate 1 mm. thickness of glass and that heavy filtration was necessary to eliminate it. A comparison of the reducing results obtained with different filters showed that these cut off the reducing effects in much the same way as they diminished the excessive decomposition of chloroform. X and γ radiations do not possess these reducing properties. It would appear that some of the more readily absorbed radiation from radon may be regarded as highly penetrating β radiation which probably decomposes chloroform like γ radiation, but which possesses reducing properties distinguishing it from this radiation. The remainder of the readily absorbed radiation would be made up of soft γ rays. The γ radiation from radon is far from homogeneous, ranging from rays of nearly 2 A.U. to less than 0.01 A.U. The long wave length or X-ray portion would be readily absorbed by comparatively small thicknesses of metal filters and chloroform. It would be completely cut off by a lead filter 3 mm. in thickness.

Energy in the form of X and γ Radiation required to decompose one gram-molecule of Chloroform.

One of the objects of the work was the determination of the amount of energy in the form of γ radiation neces-

sary to decompose a gram molecule of chloroform. The primary decomposition most probably consists in the liberation of an atom of chlorine, so that the decomposition of a gram molecule of chloroform is equivalent to the formation of a gram atom of chlorine. As it was desired to compare, on an energy basis, the decomposition effected by γ and X radiation, all the soft radiation coming from radon was cut off, for this work, by means of a 3 mm. lead filter. To obtain a reliable comparison of the effects of the two radiations experiments were conducted on the same sample of chloroform, and for both γ and X rays the time of exposure was one hour. In the γ radiation measurements, the radon was placed in the 3 mm. lead case, and the radiation passed through a thickness of 1.94 cm. Mercks' chloroform. Several concordant results showed that for 100 millicuries unfiltered radon strength the chlorine set free in one hour required 0.28 cc. N/1,000 thiosulphate solution for its titration. The lead screen absorbs 15.9 per cent. of the radiation. In passing through the 1.94 cm. of chloroform the absorption was 8.9 per cent. On this basis the curie would give a decomposition represented by 37.41 cc. N/1,000 thiosulphate. Professor Briggs of the Physics Department has kindly provided the information that the heating effect of the γ rays from radon is equivalent to 9.4 calories per hour per curie, therefore 9.4 calories in the form of γ radiation is required for the decomposition of 37.41×10^{-6} mols. chloroform, which is equivalent to approximately 251.300 cal. per mol. Cronheim and Gunther⁽³⁾ have studied the energy yield in the decomposition of chloroform by X-rays. They employed a Tungsten Target and by suitable filtration obtained an effective wave length of 0.212 A.U. They obtained 21.000 cal. per mol. as the

energy of decomposition, but they measured the decomposition by estimating the hydrochloric acid formed. As the result of some tests carried out by them on the behaviour of chlorine and hypochlorous acid with a solution of iodoform in chloroform, they concluded that in addition to hydrochloric acid, hypochlorous acid and not free chlorine is formed by the radiation of chloroform. They found that an aqueous solution of hypochlorous acid decomposes an iodoform chloroform solution with separation of iodine, but that dry chlorine does not. As moist radiated chloroform liberated iodine, when iodoform was dissolved in it, their inference was that hypochlorous acid and not chlorine is present. This conclusion is contrary to the accepted one that chlorine is produced by the radiation of chloroform, shown by the immediate liberation of iodine when the radiated liquid is shaken with a solution of potassium iodide. Cronheim and Gunther were misled by comparing the test for hypochlorous acid in the wet state with that for chlorine in the dry condition. That this is so was shown by passing a mixture of chlorine and hydrochloric acid, both dried into iodoform dissolved in dry chloroform. Iodine was liberated immediately, just as it is when iodoform is dissolved in radiated chloroform. Hence there is no reason for doubting the accepted statement that chlorine is produced by radiation of chloroform. This leads to an error in Cronheim and Gunther's values for the amount of hydrochloric acid produced in radiation, because in their method of estimating this constituent a large part of the chlorine present would be determined as hydrochloric acid. Their results for the energy required for the production of one gram molecule of hydrochloric acid are low in consequence.

In the decomposition of chloroform by X radiation a Carrell flask was found very convenient for holding the chloroform. This vessel of thin glass, circular in shape, and with flat top and bottom, could be readily supported by its filling arm in a vertical position, so that the horizontal beam of X-rays passed perpendicularly through it. Chloroform was added in sufficient quantity just to reach the base of the filling arm, thus presenting a circular cross-section of chloroform to the X-ray beam. The internal diameter of the flask was 3.28 cm., giving a cross-section of 8.42 sq. cm., with a depth of 1.00 cm. The middle of the chloroform layer was 33.0 cm. distant from the centre of the Muller X-ray tube, which was operated at 140 kV. and 6 m.a. After an hour's exposure to the radiation the chlorine content of the radiated chloroform was estimated by N/1,000 thiosulphate solution. Two determinations were made and gave 2.67 and 2.57 cc. mean 2.62 cc. N/1,000 thiosulphate. The Merck's chloroform used was taken from the same bottle as that employed for the comparative experiments in γ radiation, some of which were performed before and some after the X-ray tests.

The X-ray energy absorbed by the chloroform was estimated by means of a thermo-electric instrument designed by Dr. Moppett, biophysicist to the Cancer Research Committee, Sydney University. This instrument, a detailed account of which has already been given,⁽⁴⁾ measures the energy directly, and my grateful thanks are recorded to Dr. Moppett not only for making the apparatus available, but also for supervising the readings in the present instance. In the account of the instrument already referred to the results described were obtained by a null method and so are stated in volts;

simultaneously, however, galvanometer deflection readings were taken and showed that a deflection of 1.4 cm. on the scale corresponded to a total energy of 600 ergs per sq. cm. per sec. The present work was done with a Muller tube of lower power than the Coolidge tube previously used with the instrument. On making the measurements the Carrell flask was placed at exactly the same distance from the target of the X-ray tube as for the experiments on the amount of decomposition, and the tube was operated as before at 140 kV. and 6 m.a. The whole face of the flask was in the path of the rays, the thermo-couple being placed behind. Galvanometer deflection readings were taken with the Carrell flask, alternately empty and filled with chloroform. The average deflection with the empty flask was 0.299 cm., and with the flask filled 0.163 cm., the absorption being represented by a deflection of 0.136 cm. or 45.5 per cent. Although the deflections were small the readings were very consistent. The thermo-couple was situated 45.0 cm. from the centre of the Muller tube and the centre of the chloroform 33.0 cm. As a deflection of 1.4 cm. is equivalent to 600 ergs per sq. cm. per sec., the energy absorbed by the chloroform was $\frac{600 \times 0.136 \times (45)^2}{1.4 \times (33)^2} = 108.4$ ergs per cc. per sec. since the layer of chloroform was exactly 1.00 cm. thick. The radiation in one hour set free an amount of chlorine requiring 2.62 cc. N/1,000 thiosulphate solution. The energy absorbed by the chloroform in one hour in terms of calories was $\frac{8.42 \times 108.4 \times 3,600}{4.2 \times 10^7} = 0.0782$ cal. This was required for the decomposition of 2.62×10^{-6} mols. chloroform, equivalent to 29.800 cal. per mol.

It will be noted that there is a great difference between the amount of energy necessary to effect the decom-

position of a gram molecule of chloroform by X and γ radiation. Allowance must be made for experimental errors in determining the total energy of the X and γ radiations, but the possible errors appear to be quite outside the range of the large difference found. The comparison has been made on the assumption that the difference between the total energy of radiation, before and after passing through the chloroform, represents radiation energy absorbed by the chloroform. It has been pointed out, however, that while this may be taken as largely correct for the X radiation, in the case of the γ a very large amount of scattering must take place, so that only a portion of the apparently absorbed energy is actually absorbed. In the absence of information regarding the ratio of absorbed to scattered radiation for γ rays, no comparison can be drawn as to the effect of the actually absorbed radiation in each case. The conclusion holds, however, that the chemical effects are widely divergent for equal quantities of radiation energy disappearing in the passage of the two radiations through chloroform.

SUMMARY.

1. The decomposition produced in different thicknesses of chloroform with filtered and unfiltered radiation from radon has been studied. Excess decomposition is produced near the source with unfiltered radiation but rapidly falls off in amount.

2. Minute traces of impurities greatly influence the decomposition.

3. Secondary radiation through metal or glass appears to exert little or no effect on the decomposition.

4. Expressed in terms of energy the amounts of X and γ radiation necessary for the decomposition of one

gram molecule of the same sample of chloroform differ greatly. The figures found were 29·800 calories for X radiation and 251·300 calories for γ radiation.

ACKNOWLEDGMENT.

My thanks are due to Professor H. G. Chapman, Director of Cancer Research, for his continued interest and helpful criticism during the course of this investigation.

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A MAGNETIC SURVEY IN THE VICINITY OF A GRANITE BATHYLITH.

By EDGAR BOOTH, M.C., B.Sc., F.Inst.P.,
and J. M. RAYNER, B.Sc., A.Inst.P.

(With Plate I and six text-figures.)

(Read before the Royal Society of New South Wales, June 7, 1933.)

Introduction.

Owing to the varied magnetic susceptibilities of rocks and minerals, it is practicable to examine concealed geological structures, lava flows, certain mineral deposits, etc., by investigations of local magnetic anomalies above the surface of the ground. This procedure is referred to as the Magnetic Method of Geophysical Prospecting, and has frequently been described.¹

This paper deals with a large scale magnetic survey in the neighbourhood of Gulgong and Home Rule, covering portions of the Parishes of Gulgong and Wyaldra, County Phillip, and of Parish Stubbo, County Bligh, New South Wales (Plate I). The area covered is about eighty square miles and observations were taken at about 530 different stations.

The magnetic method was first applied in the Gulgong district in 1929 by a section of the Imperial Geophysical Experimental Survey,² when it was demonstrated that

¹ See, for example, "The Principles and Practice of Geophysical Prospecting", University Press, Cambridge, 1931.

² Reported in "The Principles and Practice of Geophysical Prospecting", *ibid.*, Chapter V.

the location of deep leads filled with basalt and hidden beneath alluvium was a suitable problem for magnetic prospecting. Large quantities of gold have been won in the past from the shallower portions of the Gulgong leads, but their extensions into deeper grounds remained unprospected. With a view to tracing these deep leads, an extensive magnetic survey was made by the Department of Mines, New South Wales, in 1930.¹

In Tertiary times the deeper portions of these leads to the north and west of Gulgong were filled by a basalt flow, which though covered by a considerable thickness of alluvium can readily be detected by the magnetometer. Although the basalt flow apparently did not reach the deep leads of Home Rule, it appeared to the authors that a wider survey of those areas, comprising the alluviated valleys of Wyaldra and Cooyal Creeks (Plate I), might well disclose features of economic significance and would be of general scientific interest. Permission to carry out the work being given by the Under-Secretary for Mines, a start was made in 1930, whilst the authors were in the district in connection with the Gulgong survey. The remainder of the work was carried out in February, August and September of 1932.

Technical Details.

Observations were made of the vertical component of the earth's magnetic field, since the variations in that component bear the most direct relation to the geology of a field in these latitudes. The intensities given on the accompanying maps and sections are relative; but at the base station on the No. 1 line of bores (on section

¹ Annual Report of the Department of Mines, N.S.W., 1930, p. 83.

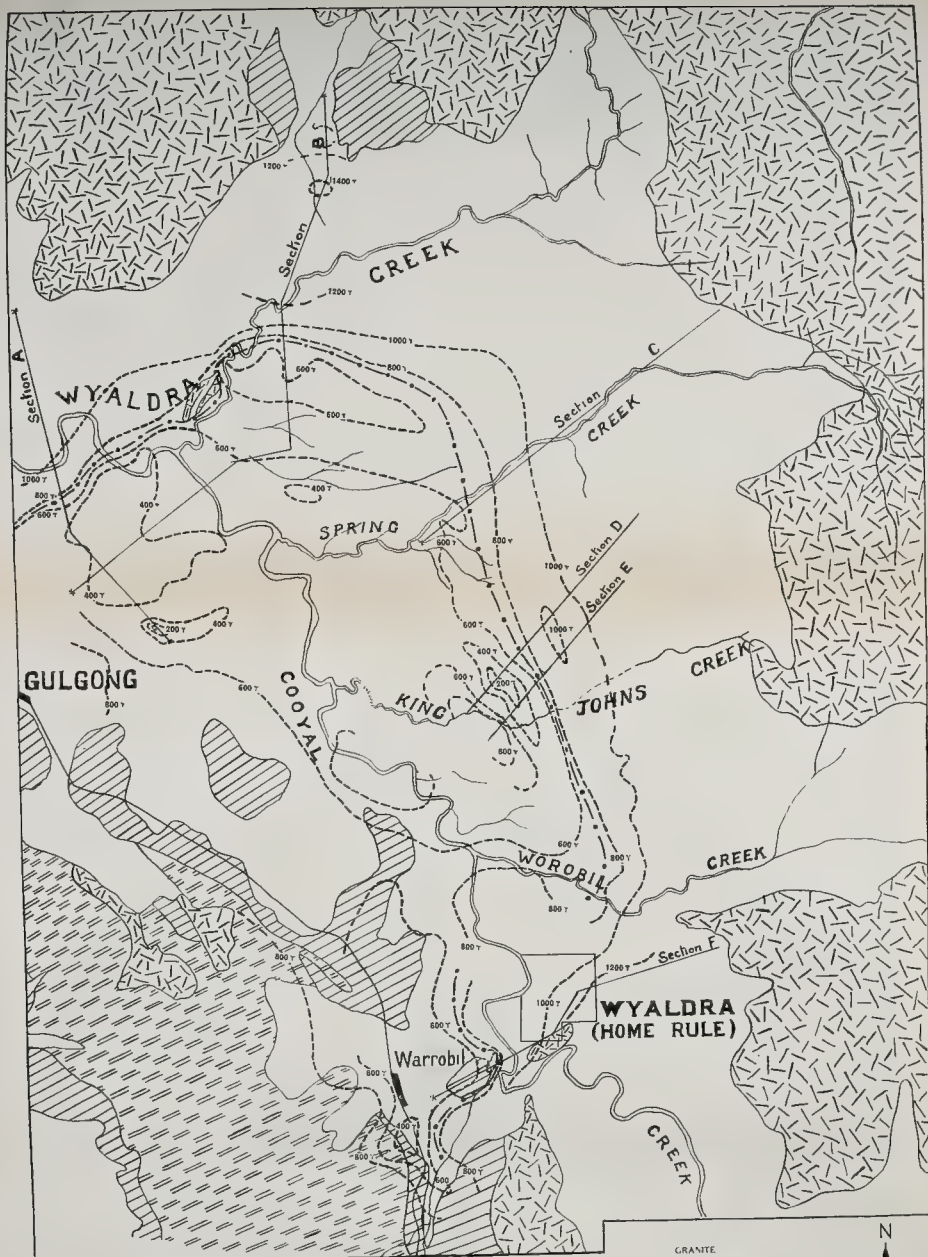
E, figure 5) the absolute vertical intensity (smooth curve value) may be taken as approximately 51, 350 γ . The mapped reading there is 787 γ .

For the greater part of the survey, two vertical field balances were in use, both of the Adolf Schmidt type, constructed by the Askania-Werke Coy. The constants of the instruments were:

| <i>Instrument Number.</i> | <i>Sensitivity.</i> | <i>Temperature Correction.</i> |
|-------------------------------|--------------------------|-------------------------------------|
| 057 | 46 γ per division | 9 γ per Centigrade degree |
| 059 | 34 γ per division | 7 γ per Centigrade degree |

The observations were corrected for (1) temperature change, (2) diurnal variation, (3) zero changes. The diurnal variation corrections were estimated from repeated check readings at base stations; in view of the large anomalies encountered this was quite permissible. The magnetometers could be read to within 4 γ , but in this survey the possible error is about $\pm 10 \gamma$; this enabled the survey to be carried out much more rapidly than if extreme accuracy had been required.

The temperature was very high during the greater portion of the work (shade, max. 116° F.), but the variations in temperature were not great. The country was mostly covered with low scrub and saplings, affording little shade. Difficulty was experienced with the leveling bubble on the tripod, which frequently became overheated and disappeared, being recalled by wetting and cooling; with one instrument an auxiliary pocket circular level had to be employed on the hottest days. By keeping the instruments shaded from the direct rays of the sun, steep temperature gradients were avoided.



Map Showing
Lines of Equal Magnetic Vertical
Intensities
Along the Edge of a Batholith in the
Vicinity of Gulgong (N.S.W.)

By EDGAR H. BOOTH, M.C., B.Sc., F.Inst.P., and J. M. RAYNER, B.Sc., A.Inst.P.
(Geological boundaries by L. J. JONES, Geological Surveyor, Department of Mines, Sydney.)

SCALE
GAUSS 0 20 40 60 80 100 120 140 160 180 200 220 240
MILES 0 1/4 1/2 3/4 1 1 1/4 1 1/2 1 3/4 2 2 1/4 2 1/2 3 5

Lines of Equal Vertical Intensity

200 T

Geology.¹

The survey was carried out chiefly above the broad flats in the valley of Cooyal Creek. After flowing in a direction somewhat west of north from the village of Home Rule, this creek junctions with Wyaldra Creek and then swings to the west around the low ridge on which Gulgong is situated, to join the Cudgegong River. The more extensive flats are on the north-easterly side of the creek and are crossed by a few small tributary streams, which rise in the low granite hills backing the flats (Plate I).

The sedimentary rocks of the area under consideration are of Silurian (?) age and consist chiefly of slates, much altered in parts. In the surrounding district, rocks of this age include also limestones, conglomerates, sandstones and shales. Along the ridge which forms the divide between Cooyal Creek and the Cudgegong River there is interbedded with the slates a series of tuffs and lava flows including felsites and andesites.

The sediments have been intruded by large masses of granite, probably in late Devonian times. The granite is of intermediate type and extends over considerable areas to the north and east of the area surveyed. The Silurian rocks are also intruded by dykes and sills of diorite of which, however, there are few outcrops. The gold which has been won from the leads was shed originally from reefs associated with these igneous intrusions.

The deep leads have developed from a Tertiary river system, the gold contents of the watercourses being now

¹ A geological survey of this area has been made by L. J. Jones, Geological Surveyor, Department of Mines, Sydney.

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covered either by olivine basalt, by alluvium, or by both.¹ The basalt flow is probably of Pliocene age and appears to have come from the north, entering the old river system about two miles north of Gulgong township. Though it backed up the tributary streams around Gulgong and flowed down the main stream for more than 20 miles to the west, no basalt was encountered in working the Home Rule leads. The floor of this mature valley is covered by a wide expanse of alluvium, river gravels and drifts, of Pliocene to Recent age; and beneath them are hidden all traces of the deep leads, and in fact all the evidence of the rocks. There is very little basalt showing in the area under consideration; but further to the west, approaching the valley of the Cudgegong River, the basalt capping of the leads has been exposed in several places.

Magnetic Properties of the Rocks.

Examinations were made of the susceptibilities of the common rock types of the district. Some were examined *in situ*, where extensive outcrops were available, and specimens were also obtained from outcrops, shafts and drill cores for laboratory study.

In the following notes the rock types are discussed in the order of decreasing magnetic susceptibility:

Basalt.

Pieces of this rock display permanent magnetism and are markedly polarised. Specimens of the basalt taken from the Gulgong deep leads had a susceptibility of approximately $5,000 \times 10^{-6}$ c.g.s. units. The susceptibility

¹ For a discussion of auriferous deep leads see M.R., No. 13, The Forbes-Parkes Gold Field, by E. C. Andrews, Dept. of Mines, Sydney.

of specimens of basalt has been determined by numerous workers, and figures ranging from $2,000 \times 10^{-6}$ to $8,000 \times 10^{-6}$ c.g.s. units have been given.

Diorite.

No direct determinations were made of the susceptibility of this rock. From the magnitude of the readings above its outcrops it is calculated that the value lies between that of the basalt and of the granite.

Granite.

The values of the susceptibilities of the different types of granite are usually quoted as ranging from 650×10^{-6} to $1,300 \times 10^{-6}$ c.g.s. units. The specimens of granites from the area surveyed have susceptibilities ranging from $1,000 \times 10^{-6}$ to $1,200 \times 10^{-6}$ c.g.s. units.

Slate.

The susceptibilities of sedimentary rocks are much lower than those of igneous rocks, and for the former group figures ranging up to 40×10^{-6} c.g.s. units are generally given. Examinations showed that as a rule in the area dealt with in this paper the slates may be considered to be the non-magnetic rocks. Exceptions to this occur in places where the slates have been mineralised or extensively altered.

Alluvium, Drifts, etc.

This superficial material, which amounts to 300 feet in thickness in the Home Rule lead, but would generally be less than 100 feet, mantles the basalt and older rocks over most of the area surveyed. It appeared to be practically non-magnetic.

RESULTS.

The essential results of the survey have been set out on the map (Plate I), lines of equal vertical intensity
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having been drawn at intervals of 200 γ . In order to correlate the distribution of magnetic intensities with rock exposures, the major geological boundaries have also been shown. The area left white is alluvium.

Six profiles (Figures 1, 2, 3, 4, 5 and 6) are given to illustrate the intensity gradients. Beneath each profile is shown the corresponding geological section, based partly on the information obtained from occasional outcrops, shafts and boreholes and partly on the interpretation of the magnetic evidence.

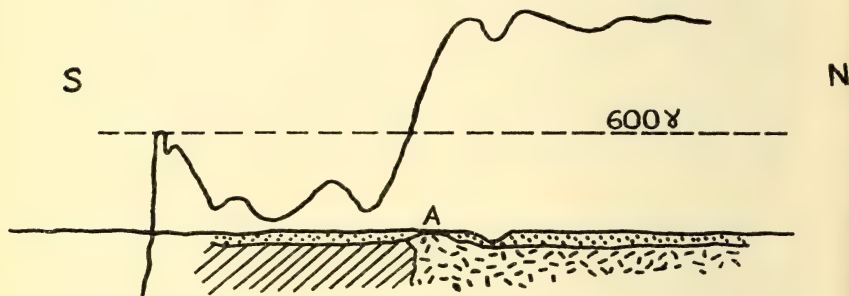


Fig. 1.—Section A (Stubbo).

Vertical Scale: 800 γ per inch, 800 ft. per inch.

Horizontal Scale: 1 mile per inch.

The sections naturally represent only a few of the traverses taken in mapping the whole area.

DISCUSSION OF RESULTS.

It is evident from the map that a magnetic anomaly of considerable magnitude has been located, which is also of regional type. On the extreme north-west of the whole area surveyed there are, in marked contrast with conditions in the eastern portions, extremely local anomalies due to the basalt filled leads. It was soon realised that basalt is practically absent from the area covered by the survey dealt with in this paper: apparently

at the time of its extrusion it backed up the main channel towards the east for only a very short distance above its point of entry. Only at one place in this particular survey (in the vicinity of the "Star of the East" shaft, to the north-east of Gulgong), did traverses pass on to the basalt flow; that shaft passes through basalt, and the survey in this section links up with that carried out earlier over the deep leads to the north and west of Gulgong.¹

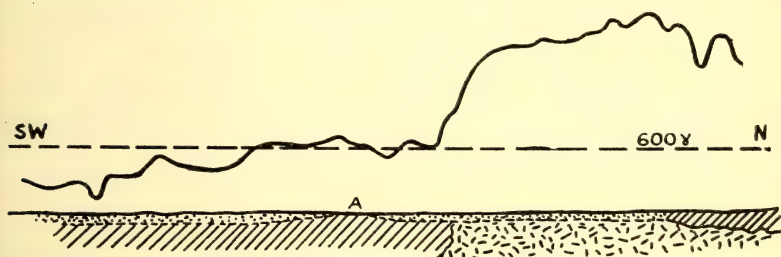


Fig. 2.—Section B (Wyaldra Creek).

Vertical Scale: 1,200 γ per inch, 1,200 ft. per inch.

Horizontal Scale: $1\frac{1}{2}$ miles per inch.

The major magnetic anomaly can only be due to the granite. The tendency of the lines of equal vertical intensity to run down the valley, keeping roughly the same distance out from the granite outcrop, is obvious. Actually this survey may be regarded as exploring portion of the magnetic field due to a great granite mass stretching far to the north and east, the approximate boundary being along the line shown in dots and dashes (Plate I).

Although hidden beneath the drifts, etc., the boundary of this bathylith can be readily located. The evidence of Figures 1, 2, 3 and 6 on this point is clear. The N.E.

¹ Annual Report of the Dept. of Mines, N.S.W., 1930, *loc. cit.*

end of Traverse No. 3 is on granite and intensities of about 1,100 γ were obtained. Going S.W. the intensities remained over 1,000 γ for about two and a half miles, and then fell sharply within the next half-mile to about 400 γ . This gradient marks the edge of the granite, which is predicted to have the position shown in the section. As noted during the Gulgong lead survey, there are no high readings to the west of Gulgong except above basalt.

In Figure 2, going from north to south, intensities of 1,200 γ to 1,400 γ give way very suddenly to intensities

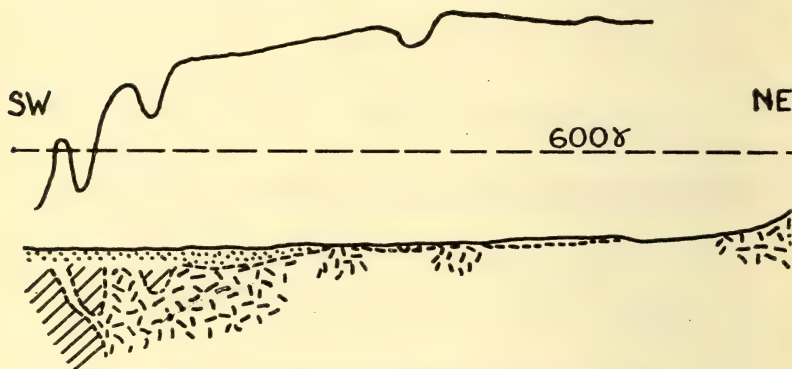


Fig. 3.—Section C (Bailey's Springs Track).

Vertical Scale: 800 γ per inch, 800 ft. per inch.

Horizontal Scale: 1 mile per inch.

of about 600 γ . From this gradient the granite boundary is deduced to have the position shown in the section. A partial check on this is furnished by the fact that some pieces of slate were found on the dump of an old shaft that has been sunk through the alluvium at A. As shown by the isodynamic lines, the slates on the northern end of the traverse given in Figure 3 can be only a thin layer, with the more magnetic granite close beneath.

Figure 1 shows the same characteristic gradient separating intensities of about 1,100 γ from those of 300 γ to 400 γ .

In Figure 6, the traverse passed over granite for about one and a half miles, as proved by an outcrop at B and a shaft at C. The intensities above the granite ranged from 900 γ to 1,300 γ , increasing towards the N.E. Passing on to the slate, of which the mapped boundary is at A, the readings are again much lower. The transition in this case is not as sharp as in the other traverses described, due partly to presence of a purely local anomaly. It is thought that the contact

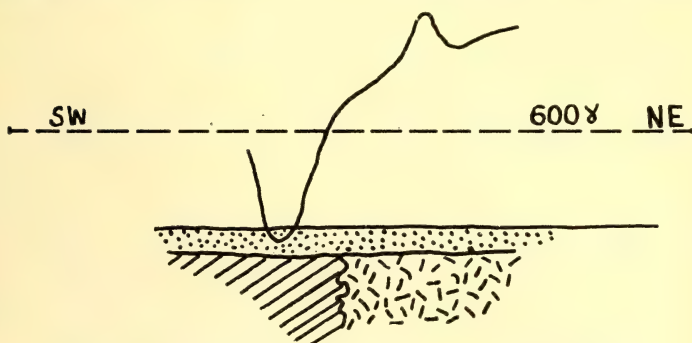


Fig. 4.—Section D (North of No. 1 Line of Bores).

Vertical Scale: 800 γ per inch, 800 ft. per inch.

Horizontal Scale: 1 mile per inch.

between the granite and the slate is more irregular than usual.

Portion of the boundary of the bathylith has thus been mapped, following close to the 700 γ line; the small outcrop of granite near the junction of Worobil and Wyaldra Creeks must be right on the boundary.

As insufficient magnetic work has been done at Wyaldra (Home Rule) definitely to place the granite boundary there, the 800 γ line to the north-west of that village is not drawn closed; it is possible that the boundary does swing right out to the north-west—but it is possible also that there is an 800 γ closed curve in that vicinity.

Contact Between the Granite and the Slate.

The sharp gradient shown by the magnetic profiles clearly indicates that the contact between the granite and the slate goes down at a very steep angle to a great depth. A probable value over a considerable depth of non-magnetic material, for this area, is 600 γ . The "edge" of the granite is plotted at 700 γ . In general, the values drop from 1,000 γ to 600 γ in about half a mile, indicating the very rapid increase in the

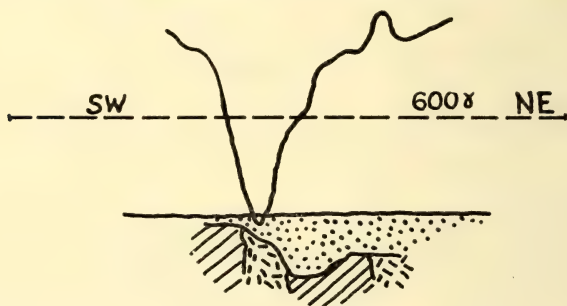


Fig. 5.—Section E (No. 1 Line of Bores). Section drawn is that indicated by line of 15 bores along traverse.

Vertical Scale: 800 γ per inch, 800 ft. per inch.

Horizontal Scale: 1 mile per inch.

covering of non-magnetic material. It is, of course, not possible to say from the magnetic readings what is the actual nature of the junction between the materials. Irregularities in the steep gradients (as in Figure 3) probably indicate apophyses, as shown in the hypothetical geological section drawn.

Although the intensity over the granite is 1,000 γ and more, and that over the slate is about 600 γ , the intensities frequently go well below the 600 γ after crossing the boundary; this is seen in Figures 4, 5 and 6, for example. This effect is frequently much greater than would be accounted for by the "southern edge" effect.

The anomaly shows considerable complexity in the vicinity of No. 1 line of bores; it seems very difficult to account for it, accepting the results of the 1901 bores (Figure 5). The lowest reading met in that vicinity was 96 γ , which is 500 γ below the reading over non-magnetic materials; the maximum readings over the granite there are only a little more than 1,000 γ , which is only 400 γ above the non-magnetic values. It would be

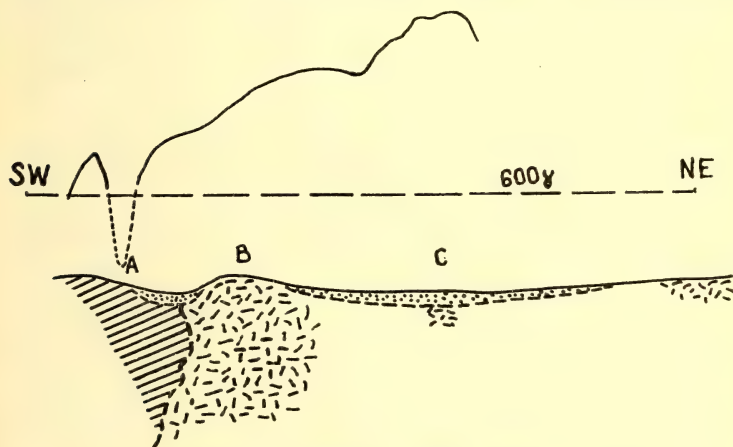


Fig. 6.—Section F (Home Rule).

Vertical Scale: 800 γ per inch, 800 ft. per inch.

Horizontal Scale: 1 mile per inch.

tempting to explain it by a reversed structure, *i.e.*, magnetic material which has been inverted after acquiring its permanent magnetism; but further work on the field may bring forward some facts of assistance. Results of seismic and of gradiometer surveys in this area also give evidence of complexity not disclosed by the section drawn to conform with the old bore records.¹

A somewhat similar anomaly, on a much smaller scale, but going down to -80 γ , is seen about two miles to the

¹ "The Principles and Practice of Geophysical Prospecting," *loc. cit.*, pp. 168-172, 224-229.

north-east of Gulgong township. It has not yet been completely mapped, not being definitely associated with the major anomaly with which this paper deals.

CONCLUSIONS AND ECONOMIC RESULTS.

In this survey portion of the magnetic field due to a large granitic mass has been investigated. The survey demonstrates how powerful a weapon is the magnetic method in determining the position of the contact between two rock types when it is obscured by superficial deposits even of considerable thickness.

Specimens of the granite were examined and found to have susceptibilities ranging from $1,000 \times 10^{-6}$ to $1,200 \times 10^{-6}$ c.g.s. units. In computing a magnetic profile for a hypothetical section for purposes of comparison with the profiles actually obtained, it was found necessary, however, to assume a susceptibility for the granite of approximately $2,000 \times 10^{-6}$ c.g.s. units. This would imply that the granite at depth is of a more magnetic or more basic type.

At the outset of the survey it was hoped that the Home Rule deep lead would be found to have associated with a small magnetic anomaly by which the lead could be traced. It was impossible, however, to pick up any such small anomaly in the presence of the intense magnetic disturbances due to the granite. What has been accomplished in this direction is the mapping of an area within which prospecting for the lead would not be warranted. For should the lead pass through the granite area mapped, then it is unlikely to carry payable gold along that part of its length, owing to the non-auriferous nature of the granite rimrock, other evidence going to

show that gold has not been transported thus far from higher up the lead.

Acknowledgments.

Acknowledgments are made to the Under Secretary for Mines, New South Wales, for permission to prepare and to present this paper.

The magnetometer No. 057 was lent for use on this magnetic survey by the Executive Committee of the Imperial Geophysical Experimental Survey. Just before the conclusion of this work it was purchased by the Commonwealth Council for Scientific and Industrial Research and the Australian and New Zealand Association for the Advancement of Science jointly and placed at the disposal of one of the authors (E.H.B.) for purposes of research. The same author wishes also to acknowledge a grant from the Australian and New Zealand Association for the Advancement of Science to assist with travelling expenses; a portion of that grant was expended during the last part of this survey.

During one period in the field the authors were assisted by certain members of a class in geophysical prospecting; B. P. Oakes, B.E., B.Sc., and W. D. Cridland, L.S., are thanked for a fortnight's assistance under extremely unpleasant conditions of country and of climate.

BROWN ROT OF FRUITS AND ASSOCIATED DISEASES OF DECIDUOUS FRUIT TREES.

I. HISTORICAL REVIEW, AND CRITICAL REMARKS CONCERNING TAXONOMY AND NOMENCLATURE OF THE CAUSAL ORGANISMS.

By T. H. HARRISON, B.Sc.Agr.,

*Hawkesbury Agricultural College, Richmond, New South
Wales, Australia.*

(Read before the Royal Society of New South Wales, July 5, 1933.)

Introduction.

Brown Rot of fruits, and the associated diseases blossom blight, twig wilt and canker of deciduous fruit trees, are often important factors in the production of these fruits. In fact, in all save a few favoured fruit producing regions, in various parts of the world, the satisfactory control of these diseases is a prerequisite to the economic production of susceptible varieties of stone fruits. This has led to considerable attention being given to taxonomic details of the organisms responsible. Our knowledge concerning them has evolved gradually, mycologists and plant pathologists of many countries making valuable contributions.

Few, however, have had the opportunity to obtain more than a local knowledge of the "Brown Rot" fungi. The literature is scattered, often in publications of somewhat limited circulation, and in consequence not always available to the isolated worker.

In some cases, contributions of taxonomic significance have been made by workers interested, for only a short time, in various aspects of the diseases and the organisms producing them. Earnest convictions, at times justified by the facts at the disposal of those forming them, have been published.

The rarity of the apothecia of all except those of the "American Brown Rot" fungus, the failure of earlier workers to fully appreciate the influence of environmental conditions upon features of taxonomic significance, and the unjustified retention of non-valid combinations, have all assisted the above circumstances to produce a state of chaos concerning the correct nomenclature to apply to the organisms causing "Brown Rot" of fruits in various parts of the world.

In 1930, after nine years' close association with the "American" brown rot fungus, as it occurred in Australia, the author was able to visit England, Europe and America. Whilst in these countries he was able to obtain field and laboratory experience of the Brown Rot organisms there present. He also had the privilege of discussing various aspects of the problem with leading workers interested in the Brown Rot fungi, and of consulting all original literature required.

At the meeting of the British Mycological Society in January, 1932, the author outlined his views, and had the benefit of suggestions made by members of that Society. Later, the matter was discussed with leading mycologists in America, and much valuable assistance was thus obtained.

The author feels that it is essential to critically review the existing taxonomic status of the various brown rot organisms, and to assess the validity of the combinations
J—July 5, 1933.

applied, in terms of standards acceptable to mycological opinion throughout the world. By this means alone is it possible to so clarify the issues that unanimity concerning taxonomy and nomenclature of the Brown Rot fungi may be possible.

HISTORICAL REVIEW.

The Position in Europe.

In 1796 Persoon⁽²⁷⁾ published under the name of *Torula fructigena* what appears to be the first authentic description of any of the organisms now referred to as "Brown Rot" fungi.

Owing to the misconceptions caused by continued mistaken references to this important record, it is here repeated verbatim:

"Torula fructigena.—Cinereo-albida subrotunda florum articulis ovatis. Tab. I. Fig. 7. *Hab.* in varii fructibus putridis *Pruni domestica*, *Amygdalus persicae* autumnno præcipua frequens in *Piris* putridis, cæspitulos, crasses subrotundus efficiens.

Tab. 1. Fig. 7. Fila Torula fructigena; unum integrum and duo articulatum disjungentia sub lente quoque representata."

It is particularly noteworthy that the pustules are described as greyish white, and that the hosts are plums and peaches, as well as members of the genus *Pyrus*—presumably apples and pears.

The above description shows clearly that Persoon had not differentiated the fungus which now bears his name from the one producing grey pustules, so common on stone fruits on the Continent. Inasmuch as there is no mention of the buff or ochraceous pustules, so distinctive a feature of *S. fructigena* on apples and pears in the autumn, and because the only reference to pustules could more properly be applied to this other fungus, it is considered that the above description does not enable us to associate Persoon's description with the Brown Rot fungus bearing

the name *Sclerotinia fructigena*. The illustration is of little help, being merely of a few conidia, without the features now recognised as distinctive of *S. fructigena*. Through the courtesy of Dr. C. L. Shear, the author, in 1932, was enabled to examine portion of Persoon's original material. This consisted of a small piece of mummied pear bearing traces of pustules only, hence no judgment could be given as to its identity. A slide, prepared from the original material by Dr. Shear, showed that the conidia had been so long desiccated that they did not resume their original shape, and hence it was impossible to determine to which of the common European Brown Rot fungi the conidia belonged.

However, during the summer and autumn on the Continent of Europe at the present time, the predominating brown rot fungus on pome fruits is *Sclerotinia fructigena*. This fungus is also present on stone fruits, often quite as abundantly as the fungus bearing greyish conidial pustules. The latter is not common on pears, and is very rare on apples. It is clear from the above that it is likely that Persoon saw the fungus *S. fructigena*, but equally possible that either he had only the grey pustuled fungus, (as his description would indicate), or that he had both fungi under observation, and failed to separate them.

Under the circumstances, the author is forced to the conclusion that it is impossible with certainty to allocate Persoon's description to any present day species of Brown Rot fungi.

In 1801 Persoon⁽²⁸⁾ transferred his fungus to the genus *Monilia*, with the following description :

"*Monilia fructigena*.—Cæspitulo subrotundo cinereo-albido; filoru mariculis ovatis. *Obs. Myc.* 1. p. 26. sub *Torula*. *Hab.* in fructibus putridis præsertim *Pyri communis* ex siccatis aut prunis immaturis etc., Primo albicans demum cæspitulis induratur et fere nigrescit."

JJ—July 5, 1933.

It can be seen that the original details have been repeated: the adjectives "cinereo-albido" have been retained for the pustules, but more emphasis than previously has been placed on the host "pear". The reference to the pustules becoming hard and black is an interesting contribution tending to further confusion, as the description applies equally well to an entirely different fungus, which the author found, on apples and pears on the Continent of Europe, in 1931, viz. *Lambertella corni-maris* V.H. That such a keen observer as Persoon failed to record the outstanding feature of *S. fructigena*, viz., the buff pustules, when describing fully the various stages of the pustules, is difficult to explain, without assuming that he did not have on this occasion, the fungus bearing that name.

No further illustrations were given with the second description.

In 1817 Kunze and Schmidt⁽²⁰⁾ published the first clear account of the fungus *S. fructigena*, under the name *Oidium fructigenum* in the following terms:

"*Oidium fructigenum*.—Cæspitibus subrotundis elevatis, floccis silaceis, sporadiis concoloribus. Im Spatsommer auf faulenden Birnen und Pfirsichen, beij Leipsig; Die Flocken sind dicht verwebt und bilden rundliche, ungefähr eine Linie im Durchmesser haltende Haufchen welche zuweilen im langen Strecken zusammenfielsen. Ihre Farbe ist, so sie die der Sporidia ein liches Ochergelb. Im altern Zustande lösen sie sich durchgangig imgrosse, ovale Sporidia auf. Oft sind diese lang zusammengekettet, und geben dem Pilze ein freindartiges Ansehn. Die Sporidia erscheinen, so wie die Flocken, unter dem Mikroskop völlig klar, die letztern gegliedert.

Wahrscheinlich ist dieser Pilz unter *Monilia fructigena* P. vielleicht auch *Epochnium monilioiodes* begrissen worden. Unsere auf Taf. 11, F. 23 gegebenen Abbildung stellt den Pilz durch die Linse C. vergrossert dar. Man vergleiche damit die Abbildung der *Torula fructigena* P. Obs. Myc. 1., Tab. 1 f.7."

Such a description needs little to support it, but in 1819 Schmidt⁽³⁹⁾ issued a collection of specimens of

German fungi, with short descriptive notes. Those dealing with *S. fructigena* are as follows:

"*Oidium fructigenum*.—Cæspitibus subrotundis, elevatis, floccis, silaceis, sporidiis concoloribus. Schmidt, Myk. Hefte 1. p. 80.

In pyris putridis autumnale. Dedit Dr. Ehrenberg, qui egregias de propagatione et germinatione hujus mucedinis observationes mox publici juris faciet."

The reference to Dr. Ehrenberg is important as, taken in conjunction with the references to follow, it shows clearly that Schmidt and Ehrenberg, if not close associates, were familiar with each other's work.

Specimen No. 225 in this collection was critically examined at the British Museum (Natural History) in London in 1931. It consists of two pieces of mummied pear fruit bearing typical buff pustules of *Monilia fructigena*.

In 1818 Ehrenberg⁽⁹⁾ published a description of a brown rot fungus producing grey pustules, in contrast to the buff pustules so clearly defined by Schmidt. In view of the tendency to ignore the species name which he created, his description, which follows, is important.

"p. 10. *Oideum* Lk. laxum mihi. 4. in pruno armeniaco putrido. p. 22. No. 4. *Oideum laxum*. floccis erectis divergentibus pallido cinereis articulis variis confluis pellucidis magnis. Habitu et colore ab *O. fructigena* Schmidt. valde differt, cujus specimina in herbario nostro servata, ab ipso amico Dr. Schmidt examinata sunt. Noster fungus *Sporotrichum* fere refert."

There can be no question that at this early stage Schmidt and Ehrenberg had clearly separated the two common Brown Rot fungi of Europe.

Persoon's next contribution shows more clearly than even the foregoing that Schmidt should be given the credit for first describing a fungus which it is possible to associate definitely with that now known as *Sclerotinia fructigena*.

In 1822 Persoon,^{(6) (29)} under the genus *Acrosporium*, included the species *fructigenum*, with the following notes:

"3. *fructigenum*. cæspitibus subrotundis effusis-que griseis pallidisque.

Monilia fructigena. Syn. Fung. p. 693. *Torula fructigena*. Pers. Obs. Mycol. 1. 80., t. 1 f. 7. *Oidium fructigenum*. Mycol. Hefte 1. p. 80. t. 2. f. 22. *Hab.* æstate in fructibus putrescentibus, natura paullo firmioribus, præsertim prunis, pyris. *Obs.* Epochnium monilioides, floccis griseis, sporidiis negrescentibus. *Link.* tam quoad characterem genericum, quam iconem longe alius fungillus, eodem tamen in loco proveniens, videtur."

It is noteworthy that while Persoon refers to Kunze and Schmidt's description of this fungus he retained almost without modification his original description of the pustules—"griseis"—and the hosts are given as members of genera *Prunus* and *Pyrus*.

This is all the more remarkable when it is considered that in the same publication,⁽²⁹⁾ the next species under the genus *Acrosporium* is Ehrenberg's species *laxum*, which is described as follows:

"4. *laxum*. floccis erectis divergentibus pallide cinereis, articulis varius confluxio pellucidis magnis. Ehrenberg syl. Mycol. p. 22. *Cresc.* in Pruno armeniaco putrido."

It should be noted that Ehrenberg's description is repeated by Persoon, who failed, however, to modify his original one of *fructigena*. The two descriptions, of what he apparently regarded as two distinct fungi, could be of one and the same fungus.

In 1830, however, Duby⁽⁸⁾ clearly differentiated between the two fungi, which Schmidt and Ehrenberg had separated. His descriptions are as follows:

"2. *O. fructigenum*. Kunze et Schmidt. Myc. Hefte 1. p. 80. t. 2 f. 22. subrotundum elevatum, filamentis suberectis simplicibus intracatis *ochraceis*, articulis ovalibus concoloribus. In Pyris et Persicis putridis. Cespites demum expanse, filamentis in tomentum intracatis."

"4. *O. laxum* Ehrenb. Sylv. Ber. p. 10, 22. filamentis erectiusculis ramosis dense aggregatis *griseis*, articulis ovalibus. In Armeniacis putrescentibus *Acrosporium laxum* Pers. Myc. 1. p. 25. Cespites primo rotundi demum confluentes et expansi tomentum breve nudis oculis sistentes."

Fries meanwhile had been assembling information for his *Systema Mycologicum*, and had published two sections of the work which has been taken as the starting point for nomenclature of the fungi with which we are concerned.

Although Vol. III part II, in which Fries⁽¹⁴⁾ gave attention to the brown rot fungi, did not appear until 1832, it is probable that the manuscript was prepared before the appearance of Duby's work in 1830, because in Fries' *Systema*, Duby is not cited. Fries adopted the attitude that but one species was represented by the two fungi above referred to, and described them under the name *Oidium fructigenum* as follows:

"3. *Oidium fructigenum*.—Cæspitulis subcompactis, primo floccis ramosis albis villosis, dein floccis simplicibus isabellinis in articulos ovales pellucidos secedentibus. *Torula fructigena*. Pers. Obs. Myc. 1. p. 25. t. 1. f. 1. omnino hujus loci; *Monilia* Pers. Syn. p. 693. Alb. et Schwein p. 365 *Acrosporium* Pers. Myc. Europ. 1. p. 24. *Oidium* Kunz. et Schmidt. Myc. Hefte 1. p. 80. Deutsch Schwamm n. 225. Link. Spec. 1. p. 22.

B. *Prunorum*. *Oidium laxum*. Ehrenb. Ber. p. 122. Link. 1. c. p. 123. *Acrosp.* Pers. Myc. Eur. 1. p. 25.

Tubercula juniora matriæ firmiter adnata passim stroma hemisphæricum nigrum ut in *Exosporis Tiliæ* offerenti, extus floccis longis æqualibus patenter ramosis dense albo-villosa. His vero evanidis aut potius in articulos constrictis floccis tantum monstrat moniliformes facile collabentes. Color variæ indicatur; equidem sapius isabellinum vidi, in lutescentem aut griseum plus minus vergentem. Occurrit quoque locis suffocatis non calabens Sporotrichi instar luxurians. Simile videtur *Sp. fructigena* Link Spec. 1. p. 4. Nil vulgatus ubique in fructibus putrescentibus; (a) in pomis, puris, (b) in prunis, Amygdalis autumnis (v.v.)."

It is evident, from the observations made of the extreme range of colour found in the pustules, that Fries had examined specimens of both Schmidt's *fructigena* and Ehrenberg's *laxa*.

Inasmuch as the position is confused, rather than clarified, by reference to Fries' *Systema*, it is necessary to turn to post-Friesian authors.

In 1833, Wallroth⁽⁴⁵⁾ published the following descriptions of the fungi bearing pustules described as "ochraceos" and "griseis" respectively:

"1569. *Oospora fructigena*. W.—Sporidiis concatenatis erectiusculis simplicibus intracitis grumulos *ochraceos* tomentosos mentientibus, fragilibus in singulos articulos ovaes secedentibus.

Oidium fructigenum Link Sp. 1. 122. Kunze et Schmidt.

Myk. Hft. 1.80 t. 2. f. 22.

Dub. Gall. II.932. *Acrosporium fructigenum*. Pers.

Myc. 1: 24.

Torula fructigena. Pers. Obs. I. t. 1. f. 7. *Monilia fructigena*.

Pers. Syn. 693.

Ad pomo quæcumque. Pyra, Persica et. Armeniaca, sub dissectove putrescentia, haud rara."

"1574. *O. laxa*. Sporidiis concatenatis erectiusculis divergenti-ramosis dense aggregatis *gryseis*, in articulos singulos ovaes secedentibus.

Oidium laxum Ehrenb. Sylv. 10, 22. Link Sp. 1. 123.

Acrosporium laxum Pers. Myc. 1.25.

Ad fructus *Pruni Armeniacæ* putres. Ehrenberg."

It is clear that this description is a valid post-Friesian one of the two fungi which Schmidt and Ehrenberg, and later Duby, had so clearly separated.

The next contribution, to which special attention must be given, is that of Bonorden,⁽⁴⁾ who, in 1851, proposed the name *Monilia cinerea* for a brown rot fungus found on cherries. His description is as follows:

"12. *G. Monilia*. Hill-Fries (2) *M. cinerea* m; fig. 78. Kommt auf faulenden fruchten vor und hat *graue hyphen* und unregelmässig-elliptische Sporen. Bildet kleine *graue, etwas bräunliche Büschel* oder Haufchen deren Mycelium in dem Früchten (Kirschen) sehr leicht beobachtet werden kann, wenn man seine perpendikuläre Schnitte davon unter das Mikroskop bringt. Das Mycelium besteht aus artikulirten Fäden, welche sich ästig in den Zellen der Frucht vergreifen und mit spitzen nicht septirten, im Inneren Körnigen frei in die Zellen hineinragenden Fäden endigen."

The figure referred to consisted of a freehand drawing of a branching conidial chain, and of several isolated conidia.

As would be expected at this early stage, no particular attention was given by Bonorden to the shape of the conidia, and in consequence the figure merely confirms the fact that Bonorden had the *Monilia* stage of a brown rot fungus.

The next contribution of importance was that of Von Thumen who, in 1876,⁽⁴³⁾ proposed the name *Oidium wallrothii* for the fungus which Wallroth had called *Oospora fructigenum*. In 1879, however,⁽⁴⁴⁾ he published a very complete account of both Schmidt's *Oidium fructigenum* and Ehrenberg's *O. laxum*, under those respective names. The thorough technical description of each, in Latin, is followed by a lengthy discussion, in German, and supported by a very complete list of synonyms, *Icones* and *Exsiccatae*.

It is noteworthy that this author clearly emphasised the difference between these fungi, and extended the host range of each. He recorded *O. fructigenum* as being:

"Ad fructus maturos elapsos et adhuc pendulos *Pyri Mali* Lin., *Pyri communis* Lin., *Persicæ vulgaris*, Mill., *Armeniaca vulgaris* L., *Corni maris* Lin., *Cydonia vulgaris*, Pers., *Mespili germanicæ* Lin., *Ubique terrarum*."

On the other hand he recorded *O. laxum* as being:

"Ad fructus maturos vel submaturos pendulos vel prostratos *Pruni domesticæ* Lin., *Pruni institæ* Lin., *Armeniaca vulgaris* Lam.—*Ubique*."

No attention was paid to Bonorden's *Monilia cinerea*.

In 1886, Saccardo and Voglino⁽³⁸⁾ published Volume IV of *Sylloge fungorum*. In this compilation all three above-mentioned species, viz., *O. fructigenum* Schmidt, *O. laxum* Ehrenberg, and *Monilia cinerea* Bonorden are dealt with in three consecutive entries under the genus *Monilia*.

No reference is made in this work to von Thumen's publication, hence it would appear that Saccardo and Voglino were not familiar with it. It is important to note the habitat recorded for each fungus by these authors. Of *M. fructigena* they wrote:

"*Hab.* in fructibus *Piri, Mali, Persicæ, Armeniacæ* in Germania, Gallia, Italia, Britannia, Belgis, Austria, America bor."

Of *M. laxa* they recorded:

"*Hab.* in fructibus putridis *Pruni Armeniacæ* in Germania (Ehrenberg)—An diversa a *M. cinerea* Bon.?"

and of *M. cinerea*,

"*Hab.* in fructibus putrescentibus *Pruni cerasi* in Germania et Italia."

Saccardo and Voglino repeated, with very minor modifications, the descriptions of the three fungi published previously. It is natural that they should have noted that there was practically no difference between their descriptions of *M. cinerea* and of *M. laxa*. The pustules of *M. cinerea* are described as *cinereis*, and those of *M. laxa* as *griseis*, although Ehrenberg had recorded that *O. laxum* had pustules which were "pallido cinereis", and Bonorden had used the phrase, "graue etwas braunliche", when speaking of the pustules of *M. cinerea*. It is difficult to understand, however, why the validity of *M. laxa*, rather than that of *M. cinerea*, was questioned by Saccardo and Voglino.

In 1893, Schröter,⁽⁴⁰⁾ who contributed the section on Fungi in Cohn's *Krypogamie Flora*, dealt only with two of the above species, i.e., *M. fructigena* and *M. cinerea*, but on the basis only of analogy transferred them to the genus *Sclerotinia*.

It is apparent from his descriptions that they refer only to the *Monilia* stage.

Of *S. fructigena* Schröter wrote "Schlauchfrucht unbekannt", and of *S. cinerea*, "Nur Conidienfruchte bekannt". The names he used (viz., *S. fructigena* and *S. cinerea*), therefore, can only be regarded as "*Nomina nuda*", having no status in taxonomy. It is important to note, too, that Schröter made no reference to *Monilia laxa*, nor did he record his *S. cinerea* from cherries, the host which Bonorden especially mentioned when he originally described *M. cinerea*, unless this be covered by the general statement "Auf fruchten von Prunus-Arten". This seems unlikely because he specially records that he had the fungus from *Prunus spinosa* and *P. domestica*.

Woronin,⁽⁵⁴⁾ in 1900, made what will always remain a classical contribution to this subject, when he published his detailed studies of the differences between the two species mentioned by Schröter, i.e., *Monilia fructigena* and *M. cinerea*. Working only with the *Monilia* stage he established beyond all question the differences in morphology and physiology of these two species, and supported his contentions by a series of magnificent illustrations. He was unsuccessful, however, in efforts to obtain the perfect stage of these fungi, although working constantly with other species of *Sclerotinia*, and knowing well the conditions for apothecial production in these other species.

In 1903, Ritzema Bos⁽⁵⁾ described in full detail the activities of the *Monilia* fungi on various fruit trees, recording that, in addition to fruit rotting, blossom blighting and twig wilting were very prevalent on Morello cherries but also occurred on plums, apples and pears. He drew attention to the fact that the sclerotia, formed by these fruit rotting fungi, were distinct, in that they consisted of incorporated fruit tissue, as well as hyphæ of the fungi. He therefore proposed the name *Stromatinia*

for these fungi, in preference to *Sclerotinia*. He accepted Woronin's differentiation between *M. fructigena* and *M. cinerea*, and added an additional means of distinguishing these two fungi. His paper deserves more attention than has been given to it, especially in view of Honey's suggestion,⁽¹⁶⁾ that the Brown Rot fungi should be placed in the genus *Monilinia*. This will be discussed more fully later.

In 1904, Aderhold⁽¹⁾ recorded the discovery of apothecia, which he thought belonged to the fungus *M. fructigena*, and in 1905, Aderhold and Ruhland⁽²⁾ published a full description, not only of apothecia obtained from mummied apples, but also of two obtained from mummied apricot. The former they named *Sclerotinia fructigena*, the latter *S. laxa*, having germinated the ascospores of each, and obtained therefrom imperfect stages which they considered quite distinct, and typical of Schmidt's *O. fructigenum* and Ehrenberg's *O. laxum*, respectively.

It is clear from the foregoing that Aderhold and Ruhland are the authors of these names, and the correct combinations therefore become *Sclerotinia fructigena* Ader. & Ruhl., and *Sclerotinia laxa* Ader. & Ruhl., respectively. These authors chose to adhere to the old specific names, but they would have been justified had they chosen entirely different ones for the perfect stage.

That Schröter had correctly forecasted the relationship of *Monilia fructigena* and *Sclerotinia fructigena* does not affect the status of the latter name, as far as Schröter's association with it is concerned. *Sclerotinia fructigena* Schröter is a "nomen nudum".

Sclerotinia laxa was first used by Aderhold and Ruhland, and inasmuch as it is a name for the perfect

stage of a fungus, properly published with an adequate description, the name must stand, unless it can be shown that the same fungus was previously described under another combination. Even assuming for a moment that *Monilia laxa* and *M. cinerea* are co-specific, the validity of the name *Sclerotinia laxa* is unshaken, for there can be no escape from the conclusion that *S. cinerea* Schröter is a "nomen nudum", according to the International Rules of Botanical Nomenclature.

Aderhold and Ruhland also published a detailed account of *Sclerotinia cinerea*, and considered that thereby they had validated the second presumption made by Schröter. Their position, however, while the outcome of logical deduction from the information at their disposal, has been severely criticised because they used for their description preserved apothecia from America, and conidial material obtained in Europe, material now believed to belong to two distinct species of fungi.

The Position in America.

In order to get the right perspective, it is now necessary to consider briefly the position concerning the Brown Rot fungi in America. This has been recently discussed by Roberts and Dunegan.⁽³⁶⁾

Following the lead of mycological opinion in Europe towards the close of the 19th century, American workers considered that the fungus causing Brown Rot of fruits, Blossom Wilt and Twig Blighting in U.S.A. was *Monilia fructigena*. Woronin's researches did not even convince European workers that at least two species were concerned with Brown Rot in that Continent, e.g., Ericksson and others contended, even recently, that but one species containing many varying forms was present.

It is natural that, when in 1902, Norton⁽²⁵⁾ discovered the apothecial stage of the American Brown Rot fungus, he should refer it to the species *Sclerotinia fructigena*.

Aderhold and Ruhland considered, for various reasons, that Norton's fungus was not identical with their *S. fructigena*, and therefore asked Norton to forward specimens for examination. This was done, and Aderhold and Ruhland concluded:

"Aus allen diesen Differenzen geht aber mit Sicherheit hervor, dass der Nortonsche Pilz eine von unseren verschiedene Art ist. Er Kann also auch nicht *Sclerotinia fructigena* heissen."

Inasmuch as the *Monilia* stage of Norton's fungus was described by various American workers as having grey pustules, occurring on many fruits, including peaches, and as they believed the fungi on apricots and peaches in Europe belonged to two different species, Aderhold and Ruhland also thought that Norton's fungus could not be *S. laxa*. They therefore concluded that it must be the perfect stage of *M. cinerea* Bon., and named it *S. cinerea* (Bon.) Schröt. It has already been demonstrated that Schröter's name *S. cinerea* is a "nomen nudum", hence the combination would more properly become *S. cinerea* (Bön) Ader. & Ruhl. Aderhold and Ruhland were mistaken, however, in assuming that the fungus known in Europe as *Monilia cinerea* Bon. was the same as that producing the perfect stage found by Norton. There is evidence available to show that the Brown Rot fungus, common throughout America, is a species distinct from any found in Europe. This evidence will be discussed more fully later on. Meanwhile it is necessary to remember that, despite the unjustified association of it with conidial material from Europe, Aderhold and Ruhland published under the name *S. cinerea*, a proper description of the perfect stage of a fungus, known definitely

to be the perfect stage of the American Brown Rot fungus.

Thus, in two years, it would appear that the same fungus had been described under two distinct names, both of them associated with certain mistaken deductions, both incorrect in some details, but both descriptions adequate enough to enable all to know definitely the fungus to which they refer.

It is here necessary to refer to a discovery of significance, made in America in 1883. A keen observer and collector, Mr. Eugene Rau, found apothecia arising from mummied peaches in his garden at Bethlehem, Pennsylvania, U.S.A. These he forwarded to Winter,⁽⁴⁷⁾ who thoroughly described them under the name *Ciboria fructicola*.

On the authority of Rehm, Saccardo⁽³⁷⁾ in 1906 transferred this fungus to the genus *Sclerotinia*.

As originally pointed out by Pollock⁽³⁰⁾ and further emphasised by Roberts and Dunegan,⁽³⁴⁾ the description given by Winter is an excellent one of the apothecial stage of the common American Brown Rot fungus. It is clear that, if Rau collected and Winter described that organism, the name *Sclerotinia fructicola* (Wint.) Rehm is the correct name to apply to it. The author considers that there can be no reasonable ground for refusing to accept the evidence available to show that Winter's description applies to the apothecia of the American Brown Rot fungus. Briefly that evidence is as follows:

Portion of the original collection, made by Rau and despatched by Winter, and at present in the Office of Pathological Collections of the United States Department of Agriculture, has been studied by Roberts and Dunegan,⁽³⁴⁾ by Honey,⁽¹⁶⁾ and by myself.

It is identical with other material definitely associated with the American Brown Rot fungus. That it is identical also with apothecial material of a European Brown Rot fungus* naturally follows. Not only do published descriptions of apothecia of these two fungi make them appear identical in that stage, but careful examination of comparable but limited material of the apothecia of these two fungi, which the author has made, fails to separate them. This is no argument, however, for assuming that Rau may have collected apothecia of the European Brown Rot fungus. It is true that this fungus has been found in North America, but only on the west coast of that large continent, and at no point within 2000 miles of Bethlehem, Pennsylvania, and separated from it by formidable and effective natural barriers.

It was first recorded by Jackson⁽¹⁷⁾ from Oregon in 1913, thirty years later than Rau found his apothecia. Since that time it has become firmly established there and also extended northward and southward in the Pacific Coast region. Despite the prevalence of the fungus, the apothecial stage has not yet been recorded from America, although a continued search has been made for it under natural conditions where apothecia of the common American Brown Rot fungus are abundant and despite carefully planned experiments to produce apothecia under artificial conditions—conditions which resulted in very heavy crops of the American Brown Rot fungus.

Inasmuch as the apothecia of the European Brown Rot fungus have only been found under experimental conditions in Europe, despite assiduous searches for them by numerous able mycologists, it would appear that this

* *Sclerotinia laxa*.

stage of that fungus is rarely developed. Observations made in England and Europe recently support that suggestion. The great majority of about 20,000 mummied fruits, exposed to various climatic conditions in England during 1930-32, disintegrated, and failed to yield apothecia under conditions which were satisfactory for the production of apothecia of the American Brown Rot fungus. Under field conditions, no apothecia were found, despite long and continued searches. The author was, however, successful in developing a few under artificial conditions.

The experience throughout the fruit growing regions of the world has been that, once a brown rot fungus has become well established in any particular locality, it does not disappear. Those who argue that Rau may have had apothecia of the European Brown Rot fungus assume that, contrary to all the evidence available concerning that organism, it was so abundant in Pennsylvania in 1881 or 1882, that in the following year (1883), an amateur mycologist was able to collect, under natural conditions, numbers of apothecia of this fungus. That the finder did not know what he had found, thinking it to be a *Peziza*, suggests that he stumbled across the material because of its abundance. It follows that they must also assume that the fungus has since entirely disappeared from the eastern half of the United States.

It seems far more reasonable to believe that the fungus Rau collected is the one which is common in the spring of most years, on mummied peaches in that region, i.e., the apothecia of the common American brown rot fungus. It is important to note, too, that in the 50 years which have passed since Rau's collection was made, apothecia belonging to no fungus other than the American Brown

Rot fungus have been collected from mummied peaches in America, although, for at least a quarter of a century, this host has been subject to close study by numerous investigators.

From the above it would seem that no other conclusion is possible, but that in 1883, Rau collected, and Winter described, the apothecia of the common American brown rot fungus. That Winter did not describe also the conidial stage of this fungus, does not affect the validity of his name *Ciboria fruticola* as the first to be given to the Discomycete named *Sclerotinia fructigena* by Norton, in 1902, and *Sclerotinia cinerea* by Aderhold and Ruhland in 1905.

The Position in Europe after 1905.

When Saccardo,⁽³⁷⁾ in 1906, transferred Winter's *Ciboria fruticola* to *Sclerotinia*, he did not realise the abovementioned connection. He discussed the taxonomic position of the fungus Norton had described under the name *S. fructigena*, and reached the conclusion that Norton's fungus should be called *S. cinerea*. He considered that the name *S. fructigena* should be reserved for the fungus Aderhold and Ruhland had described under that name.

In 1912 Westerdijk⁽⁴⁶⁾ reported the occurrence of a *Sclerotinia* arising from mummied sour cherries in Holland. Although prevented by sickness at the time from connecting the ascospores with an imperfect stage, she believed that the apothecia were the perfect stage of a brown rot fungus. Believing that *S. fructigena* did not occur on cherries, and realising from the morphology of her fungus that it could not be *S. cinerea* nor *S. laxa* as defined by Aderhold and Ruhland, she considered that the

Sclerotinia on cherries must be a species distinct. She did not, however, propose a species name.

Examination of Westerdijk's description and figures caused the author to form the opinion that the fungus she described was *S. fructigena*. The imperfect stage of this fungus is a common cause of fruit rot in cherries in Europe. In England in 1930 and 1931, the author collected it, both in the field and from cherries in the markets and retail shops. He also collected it from cherry fruits in France, Switzerland, Germany, Holland and Belgium. The author has been privileged to examine specimens preserved by Westerdijk, and to compare these with Aderhold and Ruhland's type material of *S. fructigena*, with Wormald's specimens of *S. cinerea*, and with authentic material of *S. fructicola* (Wint.) Rehm.

From a consideration of all the evidence available, the conclusion has been reached that Westerdijk in 1912 had apothecia of *Sclerotinia fructigena*, as properly described by Aderhold and Ruhland in 1905. This record, therefore, does not affect the taxonomic position. Incidentally, it was not until 1931 that the apothecia of *S. fructigena* Aderh. and Ruhl. were reported again, i.e., by Solkina in Russia.⁽⁴²⁾

Following the work of Woronin (1900), Bos (1903), Aderhold and Ruhland (1905), the majority of mycologists in Europe accepted the fact that at least two species of Brown Rot fungi were present. *Sclerotinia fructigena* (Bon.) Schröt. was the name used for the species, the imperfect stage of which produced buff pustules on the rotted fruits, and for all brown rot fungi by those who still preferred to consider that but one species was present. For the grey pustuled fungus affecting mainly

the stone fruits, causing blossom blight, twig wilt and fruit rot, the name *S. cinerea* (Bon.) Schröt. was used.

The work of Aderhold and Ruhland was responsible for the species name *laxa* being resurrected, after it had been overlooked by Schröter and Woronin, but its application was restricted, despite the work of von Thumen (1879), to apricots. There are still to be found workers, in the apricot regions of Europe, who consider the apricot *Monilia* as a species distinct from that on cherries, plums, etc., referring to it as *Stromatinia laxa* or *Sclerotinia laxa* according to whether or not they accept the suggestion of Bos (1903), e.g., Faes and Staehelin,⁽¹³⁾ Manaresi and Sacchetti.⁽²²⁾ Staehelin reiterated this view in conversation with the author in 1931.

In 1919⁽⁴⁹⁾ Wormald published the first part of his extensive studies dealing with the "Brown Rot" fungi, and in 1920,⁽⁵⁰⁾ part II of this work appeared. In the first part a very extensive and thorough *résumé* of the literature on these fungi occurs. *Sclerotinia laxa* is there noted, its synonymy cited, and the statement made:

"Since that date (1905) the name *Sclerotinia laxa* has been generally reserved for the form producing the brown rot of apricots, e.g., Faes (1914), Chiffot and Massonnat (1915), Peglion (1917)". In part II Wormald states "The same workers (Aderhold and Ruhland) were also able to obtain a *Sclerotinia* from mummied apricots, and from the ascospores obtain cultures which developed conidial pustules resembling those of *M. cinerea*. This Ascomycete they named *Sclerotinia laxa*, i.e. the ascigerous stage of Ehrenberg's *Oidium laxum* (= *Monilia laxa* Sacc. and Vogl.). They considered *Monilia laxa* to be distinct from *M. cinerea* morphologically with regard to the size of its conidia and biologically from the fact that they found it occurring plentifully on apricots when neighbouring peaches and cherries were unaffected. The size of the conidia of *M. laxa*, Aderhold and Ruhland, are given as $12.4-23.8 \times 9.3-15.5\mu$, the dimensions of those of *M. cinerea* as $9.3-14.5 \times 6.2-12.4\mu$. It is to be observed, however, that the dimensions given for *M. laxa* conform to those of *M. cinerea* when the latter is growing in summer on plums".

"To the time of writing, only one strain from apricots has been examined at Wye; this was found on dead twigs in

February, 1919. The size of the conidia was found to be from $6.5 \times 3\mu$ to $14.5 \times 9.5\mu$, with an average of $11 \times 7.5\mu$ for 100 conidia, dimensions which are the same order as those of the winter conidia of *M. cinerea* produced on mummied plums and cherries. There seems to be no valid reason, therefore, for considering the two conidial forms, *M. cinerea* and *M. laxa*, as two distinct morphological species: whether the apricot has a biologic form confined to that host remains to be proved by inoculation experiments with pure cultures" "As there are reasons for suspecting that *Monilia laxa* and *M. cinerea* are the same morphological species, it appears probable that *Sclerotinia laxa* (Ehrenb.) Ader. & Ruh., is the ascigerous stage of both the conidial forms described under these names by various authors, but until this relationship is established experimentally the present writer prefers to retain the name *Monilia cinerea* Bon., for the grey *Monilia* occurring parasitically in Europe on the commonly cultivated species of fruit trees of the genera *Pyrus* and *Prunus*."

In the following year (1921), Wormald⁽⁵¹⁾ obtained from mummied plums the apothecial stage of a brown rot fungus which he connected with a *Monilia* producing grey conidial pustules. He referred this to *Sclerotinia cinerea* (Bon.) Schröt, in preference to *S. laxa*, Ader. and Ruh. He discussed the status of *S. laxa* and criticised Aderhold and Ruhland for separating *S. laxa* and *S. cinerea* on insufficient evidence. He also stated in reference to his *Sclerotinia*, "its morphological characters are not inconsistent with those of *Sclerotinia laxa*, as defined by them" (Aderhold and Ruhland).

It should be noted that, if Wormald be right in his contention that the names *S. laxa* and *S. cinerea* both refer to the one morphological species, his description of the apothecia obtained from plum is merely a more complete one of the fungus first described by Aderhold and Ruhland in 1905. If, however, they be not synonymous, his description is the first properly published one of the fungus, the imperfect stage of which Bonorden named *Monilia cinerea*. The combination for this fungus should therefore be written *Sclerotinia cinerea* (Bon.) Wormald, and the combination should date from 1921.

Wormald's next reference to *S. laxa*, in 1927,⁽⁵²⁾ was as follows:

"The status of *S. laxa* has been discussed in a previous paper:⁽⁵¹⁾ morphologically and culturally this fungus on the apricot was found to be similar to *S. cinerea*, and there is no clear evidence at present that it is different biologically from the latter. This conclusion is supported by Chabrolin, who has made detailed observations on brown rot of apricots in the Rhone Valley. In the present paper, therefore, *S. laxa* is considered as synonymous with *S. cinerea*."

Under the latter heading, Wormald has made all subsequent references to the grey pustuled brown rot fungus found in Europe and elsewhere.

Apart from the fact that Wormald is clearly mistaken in preferring the name *S. cinerea* to *S. laxa*, should these two be synonymous, his conclusion, which is based on consideration of morphological features of the apothecia, on size of conidia, and on cultural reactions, is open to question.

As previously pointed out, the morphological details of the apothecia, normally cited in mycological literature, are of little use in separating the American brown rot fungus from the grey pustuled brown rot fungus of Europe, two fungi now regarded by Wormald and others as distinct species. It is also generally recognised, largely as a result of careful work by Wormald, that published details of conidial measurements of these fungi are of little critical value. There is no good evidence, despite the fact that measurements of thousands of conidia are available for comparison, that it is possible to separate *S. fructicola* of America and *S. cinerea* of Europe by reference to sizes of conidia. The author's experiments indicate that under the same conditions these two fungi produce mature conidia morphologically identical. Further, it would appear that Wormald had

studied only one culture of a fungus isolated from apricot. This was growing in England where apricots are cultured under abnormal conditions. It is possible that the fungus obtained from it was the one normally occurring in that country on plums and cherries and therefore not in any way representative of the apricot *Monilia* of the continent, a fungus considered by Faes and Staehelin⁽¹³⁾ in Switzerland to be distinct from *S. cinerea*. These workers had reached that conclusion after detailed investigations in the Rhone Valley in Switzerland, where apricots and other stone fruits are cultivated side by side under commercial conditions. It is clear that the criteria adopted by Wormald for grouping together *S. cinerea* and *S. laxa* would also necessitate placing under the same species the American brown rot fungus, a course contrary to Wormald's considered opinion, and also to that of many other workers on the brown rot fungi. For this reason it must be concluded from the published evidence that, while it is quite possible that *S. laxa* and *S. cinerea* are synonymous, the evidence adduced by Wormald for so considering them is no stronger than that adduced by those who consider them distinct. In that connection Miura⁽²⁴⁾ wrote:

"But he came to this conclusion because he did not see the formation of its conidial pustules on the fruit, but if he had seen this, he might not have thought so".

This is a translation of the original, which is in Japanese and refers to Wormald's statement⁽⁵²⁾ that he saw no reason why the two strains of brown rot fungi received from Miura in Manchuria under the name *Monilia laxa* should not be included under *S. cinerea*, despite minor variations in culture from the type.

Wormald, however, as a result of masterly work carried on over a period of years, was able to give a very

complete picture of the brown rot fungi in England, and to contribute largely to a clear understanding of the geographical distribution of the various species of these organisms. He confirmed so thoroughly the work of Woronin, and of Aderhold and Ruhland (in part), that it is now accepted beyond question that there are at least two species of brown rot fungi in England and in Europe. They are the organisms referred to as

- (1) *Sclerotinia fructigena*—producing buff pustules on pome and stone fruits,
- (2) *Sclerotinia cinerea*.—producing grey pustules on stone fruits and blossom wilt condition in stone fruits and in apples.

In England he distinguished two physiologic forms in each species. The former he separated by their reaction when inoculated into mature apples, the latter by the extent of penetration into the spur from the flower cluster in apple and plum trees. *S. cinerea* f. *mali* was proven to be the form entirely responsible for the blossom wilt condition in apples: *S.c.* f. *pruni* the form entirely responsible for a similar condition in plums and cherries, to cause twig wilting and cankering of those hosts, and to be the usual form isolated from rotting stone fruits.

The validity of these two biologic forms has been confirmed on many occasions since by Wormald, and also by Boyle, Murphy and Cummins,⁽⁷⁾ and later still by the author.

Killian⁽¹⁸⁾ has studied in detail the strains of *S. cinerea* found on cherries in Europe and has isolated therefrom, mainly as a result of their reaction on artificial media, what he regards as two distinct physiologic forms. These he has designated *S. cinerea* f. *avium* from sweet cherries and *S.c.* f. *cerasi* from acid cherries. The excellent figures

accompanying his original article, and his own summation of the work in 1925,⁽¹⁹⁾ show that these are not of the same status as the two forms isolated by Wormald, but merely culturally distinct strains, differing principally in growth rate. These are paralleled in every collection of fungi made and studied at all thoroughly. Experiments made by the author, to be detailed in future publications, will illustrate clearly the reasons for the contention that Killian's forms *S.c.avium* and *S.c.cerasi* are more comparable with strains noted from time to time in *S. fructicola*, e.g., Roberts and Dunegan,⁽³⁴⁾ Seal,⁽⁴¹⁾ and Ezekiel.⁽¹¹⁾

The American Fungus Again.

It is now necessary to return to a consideration of the American brown rot fungus. Following Norton's discovery of the apothecial stage of this fungus in 1902, "the name of *S. fructigena* was used generally in America until Matheny, Vallean, Conel, Bartram and others, working with fresh material, confirmed the claim made in 1905 by Aderhold and Ruhland that the common American Brown Rot fungus was more closely akin to *S. cinerea* than to *S. fructigena*."⁽¹⁵⁾

Thus Reade,⁽³²⁾ who, in 1908, published one of the most complete descriptions of this fungus extant, described it under the name *Sclerotinia* (*Stromatinia*) *fructigena* (Pers.) Nort. An unpublished manuscript submitted by Reade as a Thesis for the Master's degree of Cornell University in 1909, has recently been studied by the author. It is interesting that Reade's view then was that *Sclerotinia fructigena* (Pers.) Nort., and *S. fructicola* (Wint.) Rehm. were synonyms applicable to the American brown rot fungus.

Pollock⁽³⁰⁾ also, in 1909, drew attention to the similarity of the descriptions of *Ciboria fructicola* published by Winter⁽⁴⁷⁾ in 1883, and of *S. fructigena* by Reade⁽³²⁾ in 1908, and concluded

"If the rule of priority is to apply to the species name first associated with the perfect stage, the correct name of this fungus is *Sclerotinia fructicola* (Wint.) Rehm. instead of *Sclerotinia fructigena* (Pers.) Norton."

Apparently little notice was taken of Pollock's suggestion, for following the work of Matheny,⁽²³⁾ etc., from about 1914 onwards, the name used for the American brown rot fungus was *Sclerotinia cinerea* (Bon.) Schröt., the name first given to it by Aderhold in 1905. In 1917, Wormald⁽⁴⁸⁾ drew attention to the fact that the American form of *S. cinerea* was strikingly distinct in culture from the *S. cinerea* of Europe, and in 1920 proposed the name *S. cinerea* forma *americana* for the former fungus, thereby making three physiologically distinct races, viz., *pruni*, *mali* and *americana*, within the one species *S. cinerea*.

Roberts and Dunegan state:⁽³⁴⁾

"In 1920, Pollock, at the annual meeting of the Botanical Society of America, submitted data to show that the species of *Sclerotinia* common on American stone fruits is distinct from either *S. fructigena* and *S. cinerea* of Europe."

Again, Pollock contended that the correct name to use for the American fungus was *S. fructicola* (Wint.) Rehm.

Norton and Ezekiel also reached the conclusion that the American brown rot fungus was morphologically distinct enough to warrant specific rank and in 1924 proposed the name *S. americana* (Wormald) Norton and Ezekiel.⁽²⁶⁾ This name was adequately published and is therefore the *fourth* valid specific name to be applied to the perfect stage of a *Sclerotinia* arising from mummified peaches in North America, e.g., *S. fructicola* (1883), *S. fructigena*

(1902), *S. cinerea* (1905 and 1914) and *S. americana* (1924).

DISCUSSION.

The author has discussed above his reasons for believing that the combination *Sclerotinia fructicola* (Wint.) Rehm. is the correct one to apply to the American brown rot fungus. Assuming for a moment, however, that this is not so, there remains for consideration three combinations, all valid. In order of priority these names are *S. fructigena* Norton, *S. cinerea*, and *S. americana*.

The name *S. fructigena* has generally been reserved for the fungus defined as such by Aderhold and Ruhland. It is accepted beyond question that this fungus is not yet present in North America.⁽³⁶⁾ The species name, *fructigena*, has been in existence for a brown rot fungus since 1796, although it was not until 1817 that it was clearly defined so that it could be associated with the fungus now bearing the name. It should, however, be remembered that until Aderhold and Ruhland in 1905 made use of this species name for a *Sclerotinia* arising from mummied apples, it was validly described only in association with the imperfect stage of the fungus, a stage possessing but limited status in nomenclature. Mycologists in the past have been dominated by Schröter's presumption made in 1893, but it cannot be too strongly emphasised that *S. fructigena* Schröter is a "nomen nudum". *S. fructigena* Norton therefore antedates *S. fructigena* Aderhold and Ruhland by three years. It may be argued that reversion to the name *S. fructigena* for the American fungus would lead to considerable confusion, as this name has not generally been used for that organism since 1914. There are, however, no "nomina conservanda" in

mycology, and if the name *S. fructicola* (Wint.) Rehm. be not accepted for the American fungus, *S. fructigena* Norton must be applied to it and a new name found for the buff pustuled fungus described by Aderhold and Ruhland under *S. fructigena*.

During 1931 and 1932, the author discussed the taxonomic position of the Brown Rot fungi with most of the European and American mycologists who had a special interest in these fungi, and found that those who had previously refused to accept *S. fructicola* (Wint.) Rehm. were prepared now to do so.

The next combination requiring consideration as an alternative to *S. fructicola* is *S. cinerea* Ader. and Ruhl.. As previously recorded, despite Aderhold and Ruhland's mistake in associating the American apothecia with European conidial material, their name *S. cinerea* is a valid one, as it is an adequate description, properly published, of a *Sclerotinia* known definitely to be the perfect stage of the American brown rot fungus. Up to the present the name *S. cinerea* has been generally reserved for the grey pustuled brown rot fungus common in Europe and known in the *Monilia* stage on the Pacific Coast of North America since 1913. The combination generally employed is *S. cinerea* (Bon.) Schröt., but again it must be emphasised that *S. cinerea* Schröt. is a "nomen nudum" and the combination should read *S. cinerea* (Bon.) Wormald, and therefore date from 1921, not from 1893.

From 1914 to 1924 the name *S. cinerea* (Bon.) Schröt. was used for the American Brown Rot fungus, because in that period it was considered that the European and American fungi were not specifically distinct. Apart from Aderhold and Ruhland's use of *S. cinerea* for the

perfect stage of the American brown rot fungus, it has been used many times, together with adequate and properly published descriptions, by American workers prior to 1921, when Wormald used this combination for the *Sclerotinia* he found on mummified plums.

It is here necessary to note that the author will later present evidence of detailed studies made in England and Europe in 1930-32, as a result of which he concluded that *S. cinerea* Wormald is a synonym for *S. laxa* Aderhold and Ruhland, and that the latter name must replace *S. cinerea* as used at present in mycological literature. In the event, therefore, of both *S. fructicola* (Wint.) Rehm. and *S. fructigena* (Pers.) Nort. being rejected as suitable combinations for the American Brown Rot fungus, the name *S. cinerea* becomes the logical one for this fungus. As shown above, the author considers Aderhold and Ruhland's description a valid one, and therefore assigns to them the authorship of the name, as used in association with the American fungus. If this be not accepted, the authorship would go to Matheny,⁽²³⁾ who in 1913 used the combination *S. cinerea* (Bon.) Schröt. Such a difference of opinion regarding authorship would not in any way affect the necessity for accepting *S. cinerea* for the American fungus should *S. fructicola* and *S. fructigena* be considered unsuitable.

The fourth combination proposed for the American fungus is *S. americana* (Worm.) Nort. and Ezek. Much controversial discussion would have been saved had the facts presented above been in the possession of those who proposed, and those who supported this name. The scattered nature of the vital literature; the paucity of type material; the peculiar geographical distribution of the organisms concerned; the very gradual evolution of

really critical means of distinguishing between the various species, as well as the unjustified retention of non-valid names, have all played a part in producing confusion concerning the right name to apply to the American fungus.

The matter has been discussed at length by Ezekiel,⁽¹²⁾ Wormald,⁽⁵³⁾ and Roberts and Dunegan.^{(34) (35) (36)} It is unnecessary at this stage to review the arguments adduced by those who supported *S. americana* (Worm.) Nort. and Ezek. The new viewpoint outlined above cannot admit it as the only alternative to *S. fructicola* (Wint.) Rehm., an admission fundamental to the case presented for *S. americana*. It is clear from the historical survey presented above that the validity of *S. fructicola* (Wint.) Rehm. depends on whether or not Winter's *Ciboria fructicola* can definitely be accepted as a description of the perfect stage of the American Brown Rot fungus. The author considers that the evidence shows clearly that it could be of no other fungus. Therefore the species name *fructicola* is the first one to be associated with the perfect stage of any brown rot fungus. *Sclerotinia* (*Ciboria*) *fructicola* (Wint.) Rehm. is the correct name to apply to the American brown rot fungus, irrespective of the nomenclatorial position of the European brown rot fungi. It easily antedates all other combinations validly used in connection with the perfect stages of these organisms.

The European Species.

It now becomes necessary to turn once more to a consideration of the taxonomic position of the European brown rot fungi, to which the combinations *S. fructigena* and *S. cinerea* have usually been applied. The author has published⁽¹⁵⁾ results of experiments and observations,

which show that he has confirmed the opinion of all those who have worked with these fungi, i.e., that they are so distinct as to leave no question of their separate specific rank. Recently (1930-32) he has had the opportunity of seeing these two fungi at work in orchards in England, France, Switzerland, Italy, Germany, Holland and Belgium, and has confirmed the observations of Woronin, Wormald and others. No one, who has seen the two side by side in the field, could doubt the specific status of each. Further, he has assembled and studied approximately 100 cultures of each, from sources which cover the range of activities of each fungus, and performed many comparative experiments with representatives of each. Despite the fact that each species contains many "cultural strains", very distinct in growth rate and parasitic activity, the two species are readily separable by both cultural and morphological features, when dealing alone with the imperfect stage. Moreover, as a result of generous assistance from various sources, the author has been able to study critically, type material of the apothecia of each. Details of these studies will be reported later. At this stage it is sufficient to note that the studies decisively confirm the already accepted fact that these two fungi are distinct species. The name *Sclerotinia fructigena* (Ader. and Ruhl.) is the correct one to apply to the former species, if the name *S. fructicola* (Wint.) Rehm. be accepted for the American Brown Rot fungus.

Are *S. cinerea* and the "Apricot Monilia" Co-Specific?

The next question demanding attention is that of the specific identity, or otherwise, of the "Apricot Monilia" of Europe, and the fungus *S. cinerea* mentioned above.

It has been shown above that the published information up to 1930 left this matter in doubt.

In 1930, the author obtained from Dr. Faes of the Federal Research Station at Lausanne, Switzerland, apricots mummified by the *Monilia* considered by him to represent the typical "Apricot Monilia" of the Upper Rhone Valley, and to which Faes and Staehelin⁽¹³⁾ applied the name *Stromatinia laxa*. The cultures so obtained were so strikingly distinct from the type cultures of *S. cinerea* obtained in England, that it became necessary to visit apricot regions of Europe, both during spring and summer of 1931, in order to obtain critical field evidence and material for cultural work.

While it is a fact that in some sections apricots are the predominating stone fruit, in almost all districts visited in France, Germany, Italy and Switzerland, the apricots are growing in mixed orchards, with cherries, plums and peaches also present. Even where orchards were entirely of one type of fruit such as apricots or cherries, these were in a section where all other types were grown.

The author had the active co-operation of local mycologists in this field work, and feels certain that he made contact with the "Apricot Monilia" of Europe, and collected specimens which can be regarded as typical of it. An enormous range in colour and nature of the conidial pustules on infected parts is discernible in the field. In culture, growth forms, readily and constantly distinguishable by such cultural features as the degree of zonation, rate of growth, amount of nigrescence, and ability to sporulate, are of frequent occurrence. The apricot appears to be a host most susceptible to blossom, twig and fruit injury by the brown rot fungus. This fact, together with the consequent abundance of inoculum each season,

may possibly explain the observations of Aderhold and Ruhland⁽²⁾ and others concerning the apparent selectivity of "the Apricot Monilia".

Experiences, similar to those mentioned, have been noted from time to time by the author in connection with *Sclerotinia fructicola* (Wint.) Rehm. in Australia. It is possible for one type of fruit, such as apricot or nectarine, to show severe blossom, twig or fruit infection by this fungus while other stone fruits in the same orchard are unaffected by it. Most fruit trees, too, show a distinct gradation in varietal susceptibility to blossom blight, twig wilt and fruit rot caused by this organism, and doubtless, too, the same thing occurs in Europe as regards the reaction of varieties there grown to the fungus *S. cinerea* = *S. laxa*.

The author therefore considers that detailed field observations of the effects of the "Apricot Monilia" on the blossoms, twigs, limbs and fruits in apricot regions of Europe, a careful study of sixty different isolates from apricots growing under normal conditions in Europe, critical comparisons made of these isolates, and a large number of *S. cinerea* cultures obtained from cherries, plums and peaches in Europe, all furnish evidence to force one to the conclusion that the "Apricot Monilia" belongs to the same species as the grey pustuled Monilia occurring on other stone fruits in Europe. In other words, *Sclerotinia laxa* Ader. & Ruhl. and *S. cinerea* (Bon.) Schröt. (= *S. cinerea* (Bon.) Wormald) are synonyms.

Shall we use *S. laxa* or *S. cinerea*?

Which name is the correct one to use for this fungus? The historical review shows clearly that for the imperfect stage of this fungus the species name *laxa* was first used,

thirty-four years before the name *cinerea*; that Wallroth's post-Friesian description of *laxa* was published *nineteen* years before Bonorden's *cinerea*, and that despite changes in generic names and differences of opinion regarding validity, both have been used by mycologists up to the present day. Of greater importance, however, is the fact that Aderhold and Ruhland in 1905 first properly described the perfect stage of this fungus under the name *Sclerotinia laxa*, while the name *S. cinerea* was first properly used for this stage of the same fungus in 1921. According to the International Rules of Botanical Nomenclature therefore, *Sclerotinia laxa* (Ader. & Ruhl.) must, on the basis of priority, replace *S. cinerea* (Bon.) Schröt, wherever the latter combination has been used.

What then of the biologic forms of *S. cinerea*?

As noted previously, Wormald in 1920 divided this species found in England and Scotland into two biologic forms—*pruni* and *mali*. At that time and subsequently he demonstrated that forma *pruni* was the cause of blossom blight, twig wilt, canker and fruit rot in plums, of blossom blight, twig wilt and fruit rot in *cherries*, of blossom and spur blight in *Cydonia Japonica*, and of blossom blight and limited fruit rot in *pears*. Boyle *et alii*⁽⁷⁾ have shown that it is present also in Ireland. Wormald, Ezekiel, Barss, Roberts and Dunegan, and Posey have all made contributions which show that it is this form of *S. cinerea* which is also present (in addition to *S. fructicola*) on the Pacific Coast of North America with much the same host range. Posey⁽³⁰⁾ has noted its natural occurrence on quince fruits in Oregon. It is this form, too, that is the common grey *Monilia* causing blossom blight, twig wilt and fruit rot in stone fruits on the continent of Europe and in the Caucasus. Limited

evidence is available to show that this form also occurs in Southern Manchuria and Japan.

Wormald⁽⁴⁸⁾ has shown that forma *mali* is the cause of blossom blight, spur-kill and canker of apple trees in England and Scotland. Boyle *et alii*⁽⁷⁾ have shown that the same occurs in Ireland. Blossom blight of apples occurs on the continent of Europe, but is seldom serious. No one has yet shown that the fungus causing the disease is identical with Wormald's *S. cinerea* forma *mali*, but from descriptions given by Eriksson⁽¹⁰⁾ and Balakhonoff⁽³⁾ it would appear to be so. Although this form will readily attack apples and other fruits inoculated with it, forma *mali* has not been isolated from naturally rotted fruits, even in England, where, in favourable seasons, the blossom blight condition is serious. It is noteworthy that blossom blight caused by this fungus is unknown in America. These facts appear to cast doubt on Ezekiel's statement that "two strains isolated from a single apple from a home storage cellar in Washington, D.C., in which so far as known only domestic fruit had been stored, were classified as *S. cinerea* f. *mali*". It is significant that Ezekiel noted that these strains showed such affinities with the American brown rot fungus as to make him suggest that "forma *mali* should perhaps not be included under *S. cinerea*".

The author has studied fifteen separate isolates of *S. cinerea* f. *mali* from England and Ireland, has seen the disease caused by it and confirmed by experiment the work of Wormald⁽⁴⁸⁾ and Boyle⁽⁷⁾ in separating this form from forma *pruni*. As a result he is convinced that typical *S. cinerea* forma *mali* is very distinct from the American brown rot fungus *S. fructicola* (Wint.) Rehm.

It appears, therefore, that Ezekiel's record of *S. cinerea* forma *mali* in America was based on an error.

It is clear that the dominant form of *S. cinerea* is forma *pruni*—the form which not only has a wide host range but is found so widely distributed in the Northern Hemisphere. It is this form alone which has been connected with the perfect stage. In consequence the author regards this form as the type of the species. It is with this mainly that the author has compared the "Apricot Monilia".

The author considers that the use of the form name "pruni" is no longer necessary. Its use is undesirable also, for it has been shown that the fungus affects pears and quinces as well as members of the genus *Prunus*. For the fungus previously called *S. cinerea* f. *pruni* he considers *S. laxa* Ader. and Ruhl. sufficient. For the present it is desirable, however, to maintain the form name "mali" for the fungus Wormald proved to be the cause of blossom wilt of apples. Further studies may indicate that it is worthy of specific rank. In that event it will be necessary to remember that since 1915 there has been in existence the valid name *Sclerotinia mali* for an entirely distinct fungus, occurring in Japan.

Sclerotinia, Stromatinia or Monilinia.

There remains for discussion the question of whether or not it is necessary or desirable to replace the genus *Sclerotinia* by *Stromatinia* or *Monilinia*.

In 1928 Honey⁽¹⁶⁾ published a critical review of the generic concepts of *Sclerotinia* and closely related genera, and reached the conclusion that the Monilioid species of *Sclerotinia* represented a natural group worthy of generic rank. He proposed the name *Monilinia* for this genus

and published a technical description of it, with supporting illustrations. He stated that "the distinctive characteristics of the Monilioid species of *Sclerotinia* are first, the presence of the pseudo-sclerotium and second, the monilioid conidial stage" and further that "no other previously proposed generic or subgeneric name or concept is valid for this group".

The author agrees that the pseudo-sclerotium as used by Honey is a structure distinct from the true *Sclerotium* as seen in such organisms as *Sclerotinia sclerotiorum* (Lib.) De Bary, and that the imperfect stage *Monilia* of these fungi is of the greatest significance in indicating phylogenetic relationships.

The author is not convinced, however, that the last phrase quoted above is justified by the evidence submitted by Honey. It would appear that the genus or subgenus *Stromatinia*, originally suggested by Boudier⁽⁶⁾ in 1885 and used by Rehm⁽³³⁾ in 1887-94 and by Lindau⁽²¹⁾ in 1896 in a slightly different sense, occupies a prior place to *Monilinia*. Certainly in 1903 Bos⁽⁵⁾ definitely used the genus *Stromatinia* for the American brown rot fungus for reasons similar in part to those used by Honey. It is this same fungus that Honey uses as the type for his new genus.

The following is a translation, supplied by the Imperial Mycological Institute, England, of portion of Bos' paper:

"The *Monilia* group may also produce *Sclerotia* differing from those of *Sclerotinia* and *Claviceps*. The last named *Sclerotia* are hard bodies composed simply of densely interwoven hyphæ which together form a pseudo-parenchymatous tissue. The outer layers of such a true sclerotium are dark, while the interior is white. However, the *Monilia* sclerotia consist of hyphæ that have absorbed a portion of the host tissues. For instance, if a fruit is infected by *Monilia* it shrivels completely into a huge mass permeated by hyphæ which may be taken to represent a sort of sclerotium" "I reproduce here one of Norton's figures. I shall call the form of the fungus which this investigator cul-

L—July 5, 1933.

tured from *M. fructigena*, *Stromatinia fructigena* on account of the above described structure of the Sclerotium from which it arises, although the author named it *Sclerotinia fructigena*."

It is evident that Bos recognised clearly that the fruit rotting species of *Sclerotinia* produced a "pseudo-sclerotium" as defined by Honey, and considered the group sufficiently distinct to warrant generic rank.

It is most unfortunate that circumstances have delayed the publication of Honey's monograph, for it is clearly necessary that before final judgment be given, the full facts on which he made the decision to propose the new genus should be available.

The work of Bos is not mentioned by Honey. Moreover, the type species of *Stromatinia* is given as *S. Rapulum* (Bull.) Boud., and hence the nature of the sclerotium of this species is most pertinent to a discussion of the taxonomic position of the genus. Honey stated, however,

"The writer has not had an opportunity to study *Stromatinia Rapulum* (Bull.) Boud. to determine to the exact nature of its stroma, but it is hoped that this may be done in the near future."

The author was privileged in April, 1932, at Madison, Wisconsin, to read a typewritten manuscript which might be regarded as a draft of Honey's monograph. Assuming that it is considered desirable to give generic status to the group which Honey has called the Monilioid species of *Sclerotinia*, it is necessary for him to prove that the genus *Stromatinia* does not already satisfactorily meet the requirements of the case, if he would have his name *Monilinia* replace it.

All those who have studied the *Ciboria-Sclerotinia* complex are convinced that with the extension of knowledge concerning forms in this group, the generic distinctions become less and less clearly defined, and the

capacities of the genera concerned strained far beyond the expectations of those who created them. It is logical to expect therefore that eventually from this "miscellaneous file" there will be sorted out units which exhibit natural cohesion.

Professor H. H. Whetzel, at Cornell, is attempting such a task, one made extremely difficult by the fact that phylogenetic relationships can only be clearly seen when full details of the life histories of each member are available.

CONCLUSION.

Pending such a general review of the genus *Sclerotinia* it seems desirable to retain that generic name for the brown rot fungi.

The author considers, therefore, that the correct names to be applied at present to the various brown rot fungi are as follows:

(1) *Sclerotinia fructigena* (Ader. & Ruhl.) for the fungus whose imperfect stage causes fruit rot of both pome and stone fruits and produces thereon pustules which are usually prominent, ochraceous to buff coloured and dome shaped. It may cause spur blight and canker in both apple and peach trees by the fungus growing through the pedicel of the fruit. Its known geographical distribution is considered to be Europe and British Isles, Manchuria, China and Japan. It is this fungus which has been previously referred to as *S. fructigena* (Pers.) Schröt.

(2) *Sclerotinia laxa* (Ader. & Ruhl.) for the fungus whose imperfect stage causes fruit rotting mainly in the stone fruits and produces thereon relatively small grey to fawn conidial pustules. It also causes blossom blight,

twig wilt and canker, at times in epidemic proportions, in various stone fruit trees, in pears and Japanese quinces. Its proven geographic distribution is considered to be Europe and British Isles, Manchuria, Japan, Pacific Coast of North America. It includes all those strains of brown rot fungi which have in the past been referred to as *S. cinerea* forma *pruni*, and those which have been referred to as the "Apricot Monilia". It is considered both unnecessary and undesirable to continue the use of the form name *pruni*.

For the apple blossom wilt fungus, however, the form name *mali* should be retained, and therefore the combination, *S. laxa* Ader. and Ruhl. forma *mali* Worm. is suggested. This fungus has been proven definitely to be in the British Isles, but it appears also to be in Europe. This form has not been connected with a perfect stage.

(3) *Sclerotinia fructicola* (Wint.) Rehm. for the fungus now commonly referred to as the American brown rot fungus. It is most serious as the cause of a fruit rot, which is a limiting factor in the production of stone fruits in many areas, but may also cause blossom blight, twig wilt, and canker on most stone fruit trees. It may affect pome fruits also, but is seldom serious thereon.

It is the fungus generally distributed throughout North America, and is the only brown rot fungus in Australia and New Zealand. It is believed to be also in South America, although recorded from there under the name *S. cinerea*.

SUMMARY.

1. The author presents a historical review concerning the taxonomy and nomenclature of the organisms causing Brown Rot of fruits, and associated diseases.

2. In terms of standards set by the International Rules for Botanical Nomenclature, an attempt is made to assess the status of the various combinations used for these organisms.

3. Evidence is presented to show that *Sclerotinia fructicola* (Wint.) Rehm. is the correct name to apply to the American Brown Rot fungus.

4. The "Apricot Monilia" of Europe is co-specific with the fungus known as *Sclerotinia cinerea* (Bon.) Schröt.

5. The correct name to apply to this species is *S. laxa* Ader. & Ruhl.

6. Schröter's combinations *S. cinerea* and *S. fructigena* are "nomina nuda".

7. The name *S. fructigena* Ader. & Ruhl. must replace *S. fructigena* (Bon.) Schr.

8. The author considers it inadvisable to continue the use of the form names *cerasi*, *avium* and *pruni* in connection with the fungus previously called *S. cinerea*. The form name *mali* is considered necessary and the combination *S. laxa* forma *mali* is used.

9. For reasons given, the author prefers at present to retain the above species in the genus *Sclerotinia*. In the event of that genus being split up, the evidence available indicates that the fruit rotting species should be listed under the genus *Stromatinia* rather than under *Monilinia*.

Acknowledgments.

It is a pleasure to acknowledge the generous co-operation of mycologists and plant pathologists in most fruit growing regions of the world. Without such help, always readily given, the work leading to the above conclusions would not have been possible. My special thanks are due to Professor W. R. Brown, Imperial College of

Science, London; Mr. J. Ramsbottom, Natural History Museum, London; Dr. E. J. Butler and staff, Imperial Mycological Institute, Kew, London; Dr. G. H. Pethybridge and staff, Mycological Laboratories, Ministry of Agriculture, Harpenden; Dr. H. Wormald, Mycologist, East Malling Research Station; Dr. P. H. Joëssel, Station d'Agronomie et de Pathologie Végétale, Avignon, France; Dr. C. L. Shear, Bureau of Plant Industry, U.S.D.A., Washington, and Dr. H. P. Barss, Oregon Agricultural College, Corvallis, Oregon.

The laboratory work was carried out in the Plant Pathology laboratories of the Imperial College of Science, London, during the period that the author held the Ben Fuller Travelling Scholarship. He was at that time on leave from the New South Wales Department of Agriculture. For the facilities thus provided, the author takes this opportunity of expressing his gratitude to the authorities concerned.

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BINUCLEAR ISOMERISM OF DIPHENYL TYPE.

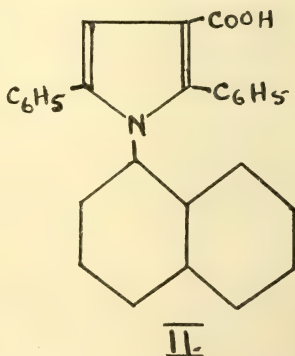
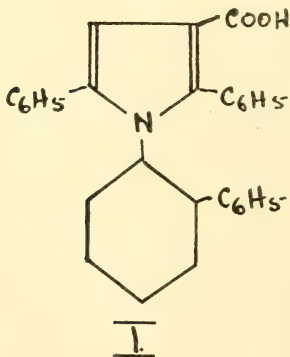
PART II.

By ALICE JEAN CHALMERS, B.Sc.,
and FRANCIS LIONS, B.Sc., Ph.D.

(Read before the Royal Society of New South Wales, July 5, 1933.)

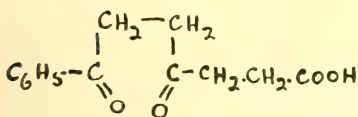
It has been previously pointed out by the authors (PROC. ROY. SOC. N.S.W. (1930), LXIV, 320) that derivatives of N-phenyl pyrrole with at least three "blocking groups" attached to the carbon atoms adjacent to the link joining the nitrogen atom of the pyrrole nucleus with the benzene nucleus should be capable of resolution into stereoisomeric forms; and it was intended to attempt the resolution of 1-o-xenyl-2:5-diphenyl-pyrrole-3-carboxylic acid (I) [*cf.* Lions, *J.A.C.S.* (1931), 53, 1176].

Before preparing this substance the 1- α -naphthyl-2:5-diphenyl-pyrrole-3-carboxylic acid (II) of Paal and Braikoff [Ber. (1889), 22, 3086-95] was prepared; and since the 8-carbon atom corner constitutes an effective

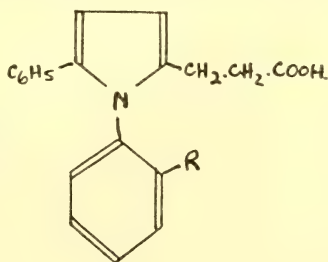


blocking group in the 1:1'-dinaphthyl series [cf. Kuhn and Albrecht, *Ann.* (1928), 465, 282-7], it was considered that this substance should be capable of resolution into stereoisomeric forms. However, on examination, it was not found possible to prepare salts of this acid with optically active bases which were suitable for fractional crystallisation, and the experiments had to be abandoned [cf. Bock and Adams, *J.A.C.S.* (1931), 53, 3519]. For this reason it was not considered to be worth while to prepare the substance (I), as it also would probably not be sufficiently strongly acid to form stable salts with suitable optically active bases. Further, Adams and his co-workers [cf. Bock and Adams, *J.A.C.S.* (1931), 53, 374, 3519; Chang and Adams, *ibid.*, 2353) have already sufficiently established the existence of stereoisomerism in substituted N-phenyl pyrroles, and its nature, for it to be relatively certain that a phenyl pyrrole such as (I) must exist in enantiomorphous forms, even if the resolution cannot be easily achieved in the laboratory.

On the other hand, because it is relatively easy to prepare N-phenyl pyrroles with three substituent groups ortho to the bond joining the two nuclei, a study of the ease of racemization of optically active forms of these, which is capable of yielding valuable information con-



III.



IV.

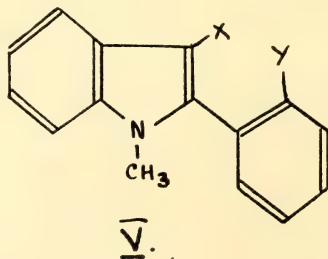
cerning the nature of the "obstacle effect", may be readily undertaken. A specially suitable substance for the first series of experiments is the phenacyl lævulinic acid (III) of Kehrer and Igler [Ber. (1899), 32, 1178; (1901), 34, 1263].

This acid can be readily condensed with ortho-substituted anilines to give the corresponding N-phenyl pyrrole acids (IV) and the result of the examination of several of these acids will be reported shortly.

Phenyl pyrroles in which the benzene ring is attached to the pyrrole nucleus by a carbon-carbon linkage and having several substituent groups in the positions ortho to this linkage do not appear yet to have been examined. However, Kermack and Slater (*J.C.S.*, 1928, 36) did attempt the resolution of 3-o-nitrophenyl indole-2-carboxylic acid which is of this type, although their experiments were not successful.

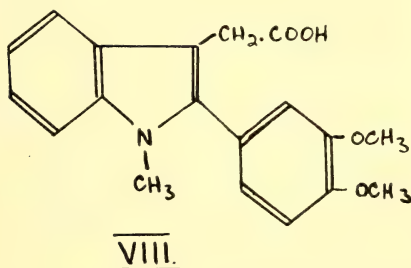
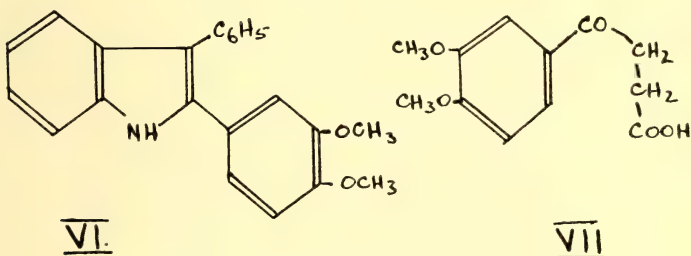
Derivatives of indole such as this with a phenyl group in the 2- or 3-position may be readily obtained by suitable application of Fischer's indole synthesis. Consequently several exploratory experiments have been carried out with the object of preparing a phenyl indole derivative suitable for resolution experiments.

In the first series, attempts were made to prepare a 2-phenyl indole (V) with a methyl group attached to



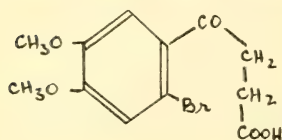
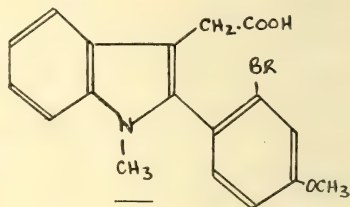
the nitrogen atom and suitable substituent groups, X and Y, in the 3- and 2'-positions.

Thus it was attempted to condense phenyl acetoveratrone with asym. phenyl methyl hydrazine with the object of closing the indole ring and then attempting the introduction of a suitable substituent group into the 2-veratryl nucleus so as to form the blocking group Y of formula (V). However, although it is possible to prepare the phenyl hydrazone of phenylacetoveratrone and from it, by treatment with alcoholic hydrogen chloride, to obtain 2-(3'-4'-dimethoxyphenyl)-3-phenyl indole (VI), phenylacetoveratrone could not be condensed with asymm. phenyl methyl hydrazine.

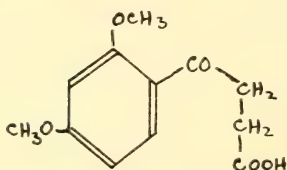
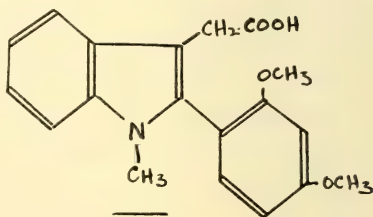


In a second series of experiments 3:4-dimethoxy benzoyl propionic acid (VII) was condensed with asym. phenyl methyl hydrazine to the corresponding hydrazone. It was possible under fairly extreme conditions to cyclise

this substance to 1-methyl-2-(3'-4'-dimethoxyphenyl)-indole-3-acetic acid (VIII) but the yield was not good. Hence attempts to prepare a 6-substituted-3:4-dimethoxy benzoyl propionic acid such as 6-bromo-3:4-dimethoxy benzoyl propionic acid (IX) and from it the corresponding 1-methyl-2-(2'-bromo-4':5'-dimethoxyphenyl)-indolyl-3-acetic acid (X) were not proceeded with. It was, how-

IX.X.

ever, observed that 2:4-dimethoxybenzoyl propionic acid (XI) could be induced to condense directly in acetic acid solution with asym. phenyl methyl hydrazine to give a small yield of 1-methyl-2-(2':4'-dimethoxyphenyl)-indolyl-3-acetic acid (XII). This is a substance with three

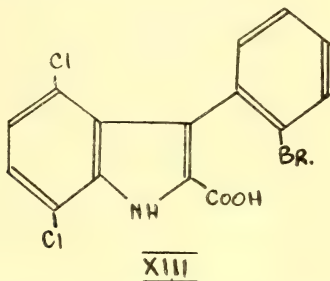
XI.XII

blocking groups in the positions ortho to the bond joining the phenyl and indolyl nuclei, and, if these are sufficiently large, might be capable of resolution into optically active forms. However, in view of the difficulty of obtaining suitable amounts of the acid, and because the methoxyl

group cannot be regarded as a large blocking group, no attempts were made to resolve this substance.

The failure of Kermack and Slater to resolve 3-o-nitrophenyl indole-2-carboxylic acid was attributed to the inability of the projecting apex of the benzenoid ring adjacent to the point of attachment of the o-nitrophenyl group to prevent free rotation. If this explanation is correct, then substitution of the hydrogen atom attached to carbon at this apex (carbon 4- of the indole system) by a larger atom or group ought to diminish the possibility of free rotation, thus increasing the possibility of existence of enantiomorphous forms.

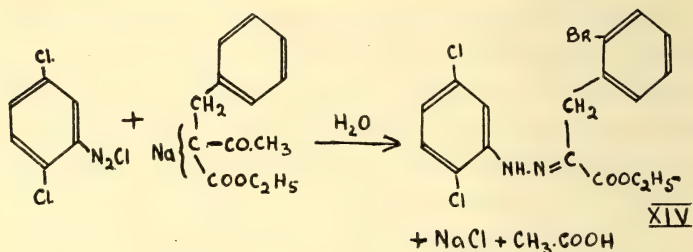
In order to test this possibility it was decided to prepare and examine 4:7-dichloro-3-o-bromophenyl-indole-2-carboxylic acid (XIII).



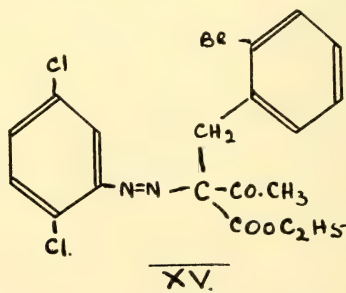
In this substance the bromine atom of the o-bromophenyl group is a large atom; and also there is a relatively large chlorine atom attached to carbon atom 4-, thus decreasing the possibility of free rotation of the bromophenyl group about the bond linking it to the indole nucleus.

It was proposed to prepare the indole acid (XIII) by coupling diazotised 2:5-dichloroaniline with the sodium derivative of ethyl α -acetyl- β -(o-bromophenyl) propionate in aqueous alcoholic solution, when it was anticipated

that the 2:5-dichlorophenylhydrazone of ethyl-*o*-bromophenyl pyruvate (XIV) would be formed.



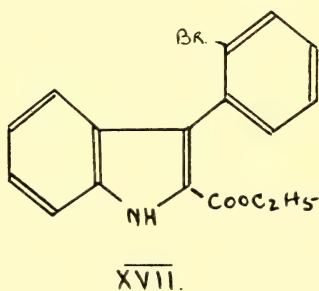
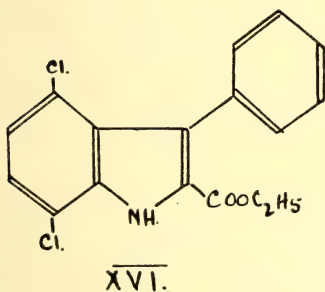
This on treatment with alcoholic hydrogen chloride should yield the ester of the acid (XIII). On carrying out the experiments it was found that coupling of diazotised 2:5-dichloroaniline with ethyl α -acetyl- β -(*o*-bromophenyl) propionate in alkaline aqueous alcoholic solution led to formation of a brown oil which could be crystallised and melted at 142-143°. Its analysis pointed fairly clearly to it having the constitution of an ethyl α -(2:5-dichlorobenzene-azo)- α -(*o*-bromobenzyl)- α -acetyl acetate (XV).



That the acetyl group had not been extruded during the coupling reaction is worthy of comment, although similar examples have been recorded, for example, by Kalb, Schweizer, Zellner and Berthold [Ber. (1926), 59, 1860].

Treatment of the substance (XV) with alcoholic hydrogen chloride led to elimination of the acetyl group and the ester (XIV) melting at $108-109^{\circ}$ was formed; but even prolonged action of acid on this substance failed to produce any indole derivative. The ester (XIV) could be hydrolysed to the corresponding acid m.p. $196-197^{\circ}$, and this could be re-esterified with alcoholic hydrogen chloride, with re-formation of (XIV).

It was at first thought that the failure to obtain an indole derivative might be due to the inhibiting influence of the two chlorine atoms, particularly as 2:5-dichloro aniline cannot be condensed with acetylacetone to a quinoline derivative in the Combes synthesis (*cf.* Roberts and Turner, *J.C.S.*, 1927, 1833). However, coupling of diazotised 2:5-dichloroaniline with the sodium derivative of ethyl α -acetyl- β -phenyl propionate led to formation of an orange coloured oil which on treatment with alcoholic hydrogen chloride readily formed ethyl- β -phenyl-4:7-dichloro-indole-2-carboxylate (XVI).

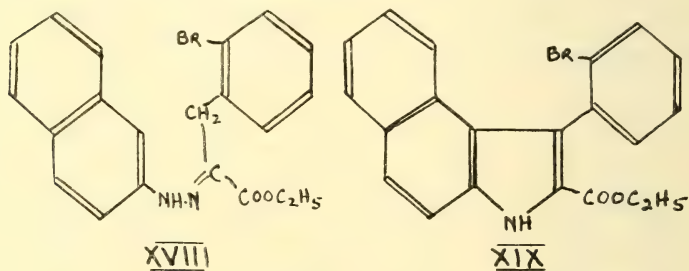


It was also found that diazotised aniline could be coupled with the sodium derivative of ethyl α -acetyl- β -(*o*-bromophenyl) propionate to give a crude oily hydrazone which on treatment with dry hydrogen chloride

readily formed ethyl 3-(o-bromophenyl) indole-2-carboxylate (XVII).

It thus seems as though the failure to cyclise the 2:5-dichlorophenyl hydrazone of ethyl-o-bromobenzyl pyruvate (XIV) to an indole must be attributed in some measure to the steric effects of the neighbouring halogen atoms—suggesting that in a compound such as (XIII), if obtainable, the plane of the indole system would be different from the plane of the attached benzene ring.

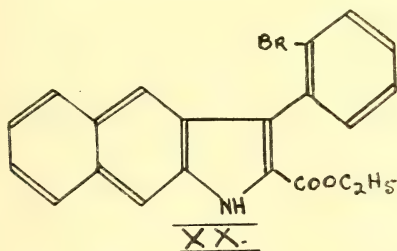
The substance (XIII) being thus not available for examination it was decided to couple diazotised β -naphthylamine with the sodium derivative of ethyl α -acetyl- β -(o-bromophenyl) propionate so as to obtain the β -naphthylhydrazone of ethyl o-bromophenyl pyruvate (XVIII) and to cyclise this with alcoholic hydrogen chloride to the corresponding ethyl 3-(o-bromophenyl)-4:5-benzo-indole-2-carboxylate (XIX).



It was found on experiment that the crude oily hydrazone (XVIII) could be converted on cyclisation into a mixture of two isomeric indole esters, one of which was probably (XIX) and the other the "linear" indole ethyl-3-o-bromophenyl-5:6-benzoin-dole-2-carboxylate (XX). Although the production of such a substance as (XX) is to be considered as exceptional, it should be remembered that heat treatment of phenyl β -naphthylamine leads to

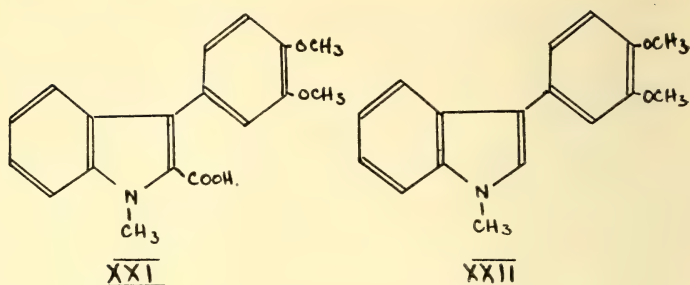
exclusive formation of "linear" naphtho-carbazole, no trace of the "angular" compound being formed [Kehrmann, Oulevay and Regis, Ber. (1913), 46, 3712].

Hydrolysis of the esters (XIX) and (XX) leads in each case to the corresponding acid. These, however, were found to be too weak to form suitable salts with optically active bases, and attempts to resolve them could not be made. It was essayed to bring up the strength of these acids by nitration, and mononitro acids were prepared, but they, too, gave unsatisfactory results in attempted resolution experiments.



It is proposed now to attempt the preparation of a sulphonic acid derivative of (XX) by commencing with a β -naphthylamine sulphonic acid instead of β -naphthylamine, and the results of these experiments will be communicated to the Society at a later date.

Finally, it is worthy of mention that when it was attempted to prepare the asym. phenyl methyl hydrazone of 3:4-dimethoxyphenyl pyruvic acid by warming the acid and the hydrazine together in alcoholic solution, 1-methyl-3-(3':4'-dimethoxyphenyl) indole-2-carboxylic acid (XXI) was formed directly. Treatment of this in alcoholic solution with hydrogen chloride, which should have yielded an ester, led instead to the formation of 1-methyl-3-(3':4'-dimethoxyphenyl) indole (XXII).



The great ease with which asym. phenyl methyl hydrazones can be converted into indoles has frequently been observed [cf. Fischer, *Annalen*, 236, 116; Kermack and Slater, *J.C.S.*, 1928, 36].

EXPERIMENTAL.

1- α -Naphthyl-2:5-diphenyl pyrrole-3-carboxylic acid (II).

Phenacyl benzoyl acetic ester, prepared in 80% yield by the method of Paal [Ber. (1888), 21, 1485] by condensing ω -bromoacetophenone with the sodium derivative of ethyl benzoylacetate, was found to melt at 65-68° (Paal gives 55-58°). It was condensed with α -naphthylamine by the method of Paal and Braikoff [Ber. (1889), 22, 3086-95] to ethyl-1- α -naphthyl-2:5-diphenyl pyrrole-3-carboxylate, m.p. 181-182°; and this ester hydrolysed to the corresponding acid m.p. 278-280° (Paal and Braikoff give 271-272°). Unsuccessful attempts were made to form salts of this acid with brucine, strychnine and l-menthylamine, but the unchanged acid was recovered in each instance.

Phenylhydrazone of Phenylacetoveratrone.

Phenylacetoveratrone (7 g.; prepared by condensation of phenylacetyl chloride with veratrole in presence of anhydrous aluminium chloride [cf. Kaufmann and Müller, Ber. (1918), 51, 123-130] and phenylhydrazine

(4 g.) were dissolved and heated under reflux in absolute ethyl alcohol (40 c.c.) for 4 hours. On cooling and careful addition of water phenylacetoveratrone (5 g.) crystallised out and was recovered. The residual solid (4 g.) was then recrystallised from methyl alcohol and thus obtained in yellow prisms m.p. $153-154^{\circ}$.

Found N = 8.3%; calculated for $C_{22}H_{22}O_2N_2$, N = 8.1%.

2-(3':4'-Dimethoxyphenyl)-3-phenyl indole (VI).

A hot solution of the above phenylhydrazone (3 g.) in absolute ethyl alcohol (40 c.c.) was rapidly saturated with dry hydrogen chloride and allowed to stand. When it had cooled, water was added and the precipitated white crystalline material recrystallised from alcohol. Colourless crystals melting at 197° were obtained. Their solution in alcohol exhibits a marked blue fluorescence.

Found N = 4.2%; calculated for $C_{22}H_{19}O_2N$, N = 4.3%.

Phenylacetoveratrone could not be induced to condense with asym. phenyl methyl hydrazine, even by prolonged refluxing in alcoholic solution.

3:4-Dimethoxybenzoyl propionic acid (VII).

This acid has been recently prepared in very good yield by Haworth and Mavin (*J.C.S.*, 1932, 1486). In our experiments, which were carried out earlier, the reaction between veratrole (90 g.), succinic anhydride (30 g.) and anhydrous aluminium chloride (100 g.) was carried out in presence of carbon disulphide (100 c.c.), and it was found possible to obtain a 51% yield of the acid, m.p. 163° .

Found C = 60.3, H = 6.0%; calculated for $C_{12}H_{14}O_5$, C = 60.5, H = 5.9%.

6-Nitro-3:4-dimethoxybenzoyl propionic acid.

3:4-dimethoxybenzoyl propionic acid (1 g.) was slowly added with stirring to nitric acid (10 c.c.; D 1.42) at 0° .

When nearly all had dissolved a yellow solid commenced to separate. The mixture was finally warmed at 30° for 30 minutes and then poured on to ice. The precipitated nitro-acid was collected and recrystallised from methyl alcohol. It was thus obtained in long yellow needles, m.p. 115° .

Found N = 5.2%; calculated for $C_{12}H_{13}O_7N$, N = 5.0%.

Asym. phenyl methyl hydrazone of 3:4-dimethoxybenzoyl propionic acid.

A solution of 3:4-dimethoxybenzoyl propionic acid (8 g.) and asym. phenyl methyl hydrazine (5 g.) in ethyl alcohol (50 c.c.) was heated under reflux for 3 hours. On cooling and adding a few drops of water the hydrazone crystallised out in bright yellow prisms, the yield being practically quantitative. Recrystallised from ethyl alcohol the substance melted at 171° to a dark green liquid.

Found C = 66.5, H = 6.4%; calculated for $C_{19}H_{22}O_4N_2$, C = 66.7, H = 6.4%.

1-Methyl-2-(3':4'-dimethoxyphenyl) indolyl-3-acetic acid (VIII).

The cyclisation of the hydrazone just described was attended with difficulty. Heat treatment with boiling 10% aqueous sulphuric acid led to hydrolysis, 3:4-dimethoxyphenyl propionic acid being recovered. Cyclisation could not be effected by saturating an alcoholic solution of the hydrazone with dry hydrogen chloride and then heating. Passage of dry hydrogen chloride through a cold xylene solution of the hydrazone led to separation of a yellow solid which appeared to be the hydrochloride of the hydrazone. However, passage of dry hydrogen chloride through a boiling solution of the hydrazone in xylene led to crystallisation of a brown substance on cooling. Recrystallised from xylene it melted at $153-156^{\circ}$.

Found C = 70.2, H = 6.0%; calculated for $C_{19}H_{19}O_4N$, C = 70.2, H = 5.9%.

Treatment of this acid (2 g.) in carbon tetrachloride solution with bromine led to immediate separation of an orange solid, soluble in methyl alcohol, ethyl alcohol, acetic acid and benzene. When freed from solvent it became a brown sticky mass. Heat treatment of its solution in benzene led to evolution of hydrobromic acid and on cooling a crystalline solid separated. Recrystallised from acetone this was obtained in small colourless crystals melting at 206-207°.

Found N = 3.3%; calculated for $C_{19}H_{18}O_4NBr$, N = 3.5%.

The substance thus appears to be a monobromo-1-methyl-2-(3':4'-dimethoxyphenyl) indolyl-3-acetic acid.

1-Methyl-2-(2':4'-dimethoxyphenyl) indolyl-3-acetic acid (XII).

If 2:4-dimethoxybenzoyl propionic acid [Perkin and Robinson, *J.C.S.* (1908), 93, 506], is heated with asym. phenyl methyl hydrazine in alcoholic solution there is apparently no reaction. However, if a solution of the acid (4 g.) and the hydrazine (2 g.) in glacial acetic acid (40 c.c.) was gently refluxed it rapidly became yellow, green, and finally dark blue after about 15 minutes' heating. After 1 hour most of the acetic acid was distilled off and a blue crystalline solid m.p. 210° isolated from the residue. Recrystallised from methyl alcohol, beautiful white crystals (1 g.) were obtained, the blue material remaining undissolved.

Found C = 70.8, H = 6.1, N = 4.5%; calculated for $C_{19}H_{19}O_4N$, C = 70.2, H = 5.8, N = 4.3%.

Equivalent weight: Found 315; calculated for $C_{19}H_{19}O_4N$, 325.

It was possible to recover a small amount of the original acid (1 g.; m.p. 144°) from the reaction mother liquor by extraction with ether.

Ethyl α -acetyl- β -o-bromophenyl propionate.

To a cooled solution of sodium (9.2 g.) in absolute ethyl alcohol (100 c.c.) was carefully added ethyl acetoacetate (52 g.) with shaking. After 10 minutes o-bromobenzyl bromide (100 g.; cf. Kenner and Wilson, *J.C.S.*, 1927, 1110) was gradually added. Sodium bromide soon commenced to separate and the liquid was finally heated under reflux for several hours. Most of the alcohol was then distilled off, and the residue poured into water. The separated oil was taken up, washed and dried in ether, and the solvent removed. The residual oil was then fractionated in vacuo. A fraction (66 g.; 56% of theory) boiling at $165\text{--}180^{\circ}/2$ mms. was collected.

Found C = 51.4, H = 4.8%; calculated for $\text{C}_{13}\text{H}_{15}\text{O}_3\text{Br}$, C = 52.2, H = 5.0%.

Ethyl- α -(2:5-dichlorobenzene-azo)- α -(o-bromobenzyl)- α -acetyl acetate (XV).

Into a cold solution of ethyl α -acetyl- β -o-bromophenyl propionate (40 g.) in alcohol (350 c.c.) was stirred a cold solution of sodium hydroxide (6 g.) in water (20 c.c.) and then after 1 minute a suspension of the diazonium chloride prepared from 2:5-dichloroaniline (23 g.), hydrochloric acid (45 c.c.) and sodium nitrite (10 g.) solution was rapidly added. A reddish-brown oil separated. After 15 minutes stirring, water was added and the oil taken up in ether, well washed with water, dried over anhydrous sodium sulphate and the solvent removed. The residual oil was induced to crystallise by solution in a little chloroform and allowing to stand. After recrystallisation

from the same solvent yellow crystals melting at $142-143^{\circ}$ were obtained.

Found C = 47.6, H = 3.9, N = 6.3, Cl = 15.3, Br = 17.2%; calculated for $C_{19}H_{17}O_3N_2Cl_2Br$, C = 48.3, H = 3.6, N = 6.0, Cl = 15.0, Br = 17.0%.

Ethyl o-bromophenyl pyruvate 2:5-dichlorophenyl hydrazone (XIV).

After passing dry hydrogen chloride into a solution of the above described azo compound (XV) in dry alcohol, followed by cooling, a yellow solid separated. Recrystallised from alcohol it was obtained in long pale yellow needles melting at $108-109^{\circ}$.

Found C = 48.7, H = 3.7, N = 6.5, Cl = 16.5, Br = 18.6%; calculated for $C_{17}H_{15}O_2N_2Cl_2Br$, C = 47.5, H = 3.5, N = 6.5, Cl = 16.5, Br = 18.6%.

o-Bromophenyl pyruvic acid 2:5-dichlorophenyl hydrazone (XIV)

was readily obtained from the above ester (XIV) by hydrolysis with alcoholic potash. After recrystallisation from methyl alcohol it was obtained in red prisms melting at 197° .

Found C = 45.5, H = 3.2, N = 6.7, Cl = 17.4, Br = 19.6%; calculated for $C_{15}H_{11}O_2N_2Cl_2Br$, C = 44.8, H = 2.8, N = 7.0, Cl = 17.6, Br = 19.9%.

The equivalent weight was found to be 409. $C_{15}H_{11}O_2N_2Cl_2Br$ requires E.W. = 402.

By treatment with dry alcoholic hydrogen chloride it is possible to esterify this acid so as to reform the ester (XIV). Apparently there is no tendency towards the formation of an indole derivative.

Ethyl-3-phenyl-4:7-dichloroindole-2-carboxylate (XVI).

To a cold solution of ethyl α -acetyl- β -phenyl propionate (16 g.) in ethyl alcohol (150 c.c.) was added a cold
N—July, 5, 1933.

solution of sodium hydroxide (4 g.) in water (15 c.c.); after stirring for 1 minute a suspension of the diazonium chloride prepared from 2:5-dichloroaniline (20 g.), hydrochloric acid (30 c.c.) and a solution of sodium nitrite (6 g.) was added in one lot. A yellowish-red oil separated. Stirring was continued for 10 minutes, water was added and the oil taken up, washed and dried in ether. After removal of the solvent the residual 2:5-dichlorophenyl hydrazone of ethyl phenyl pyruvate was dissolved in dry ethyl alcohol and the solution rapidly saturated with dry hydrogen chloride. The solution became very dark in colour and after a short time a solid commenced to crystallise. Finally water was added and the solid collected, washed and then recrystallised from methyl alcohol. It was thus obtained in fine white rosettes melting at 130°.

Found C = 61.0, H = 4.0, N = 3.9%; calculated for $C_{17}H_{13}O_2NCl_2$, C = 61.1, H = 3.9, N = 4.2%.

3-Phenyl-4:7-dichloroindole-2-carboxylic acid.

The ester (XVI) was refluxed for several hours with 10% alcoholic potassium hydroxide. Most of the alcohol was then distilled off, water was added, and after treatment in the hot with animal charcoal the solution filtered, cooled and acidified with dilute hydrochloric acid. Recrystallised from methyl alcohol in white needles the acid melted at 246-248°.

Found C = 58.4, H = 3.0, N = 4.7%; calculated for $C_{15}H_9O_2NCl_2$, C = 58.8, H = 2.9, N = 4.6%.

Ethyl-3-o-bromophenyl indole-2-carboxylate (XVII).

To a cold solution of ethyl α -acetyl- β -o-bromophenyl propionate (10 g.) in ethyl alcohol (100 c.c.) was added a cold solution of sodium hydroxide (2 g.) in water

(10 c.c.) and then without delay a diazonium solution from aniline (3.1 g.), hydrochloric acid (10 c.c.) and sodium nitrite (2 g.) was stirred in. An orange coloured oil separated. After dilution with water the oil was taken up, washed and dried in ether and the solvent removed. The crude oily residual phenylhydrazone of ethyl o-bromophenyl pyruvate was then dissolved in ethyl alcohol and the solution saturated with dry hydrogen chloride. Ammonium chloride separated. Eventually water was added and the precipitated oil was taken up and dried in ether. After removal of this solvent the residual oil was induced to crystallise, by scratching with toluene. It was recrystallised from alcohol and obtained in small yellow prisms melting at 164-165°.

Found N = 4.1%; calculated for $C_{17}H_{14}O_2NBr$, N = 4.1%.

3-o-Bromophenyl indole-2-carboxylic acid.

Hydrolysis of the above ester (XVII) with alcoholic potash led to formation of the corresponding acid which could be crystallised from chloroform and was thus obtained in small white crystals containing a half molecular proportion of chloroform of crystallisation, m.p. 231-232°.

Found N = 3.8%; calcd. for $(C_{15}H_{10}O_2NBr)_2CHCl_3$, N = 3.7%.

Loss on heating = 15.2%; calculated for $(C_{15}H_{10}O_2NBr)_2CHCl_3$, $CHCl_3$ = 16.0%.

Recrystallised from benzene the acid was obtained in small white prisms which melted at 235° after softening at 224°.

Found N = 4.4%; calculated for $C_{15}H_{10}O_2NBr$, N = 4.4%.

No attempts to resolve this acid have so far been made. Since the bromine atom constitutes a much more effective blocking group than a nitro group it is conceivable that in this substance the 4- carbon apex of the benzene ring of the indole nucleus will prevent free rotation of the bromophenyl nucleus about the bond joining it to the indolyl nucleus, thus giving rise to stereoisomerism. The result of resolution experiments will be reported later.

Ethyl 3-o-bromophenyl-4:5-benzo-indole-2-carboxylate (XIX) and Ethyl 3-o-bromophenyl-5:6-benzo-indole-2-carboxylate (XX).

To a cold solution of ethyl- α -acetyl- β -o-bromophenyl propionate (30 g.) in ethyl alcohol (260 c.c.) was added a cold solution of sodium hydroxide (5 g.) in water (20 c.c.) and then without delay a diazonium solution prepared from β -naphthylamine (14.3 g.) concentrated hydrochloric acid (35 c.c.) and sodium nitrite (7 g.) solution was run in. The precipitated oily hydrazone was isolated and dried in ether in the usual way and after removal of the solvent was dissolved in alcohol and the solution saturated with hydrogen chloride. The red colour of the solution persisted, so it was boiled under reflux for 2 hours. The colour deepened and ammonium chloride separated. On cooling the solution a white crystalline solid (25 g.) separated. By repeated fractional crystallisation from alcohol this was eventually separated into two substances A and B.

A (13 g.) represented the ester less soluble in alcohol. After final recrystallisation from alcohol it was obtained in colourless crystals melting at 249° .

Found N = 3.6%; calculated for $C_{21}H_{16}O_2NBr$, N = 3.6%.

B (10 g.) was the ester more soluble in ethyl alcohol. It was obtained pure by recrystallisation from methyl alcohol in colourless needles m.p. 217° .

Found N = 3.6%; calculated for $C_{21}H_{16}O_2NBr$, N = 3.6%.

**3-o-Bromophenyl-4:5-benzo-indole-2-carboxylic acid and
3-o-Bromophenyl-5:6-benzo-indole-2-carboxylic acid.**

Hydrolysis of the above described esters A and B with 10% alcoholic potash led to formation of the corresponding acids A' and B'.

The acid A' obtained from the ester A was recrystallised from acetone and was obtained in colourless crystals containing one molecule of acetone of crystallisation, which softened at 120° and melted at $228-230^\circ$.

Found N = 3.3%; acid equivalent = 414; calculated for $C_{19}H_{12}O_2NBr$, C_3H_6O , N = 3.3%; acid equivalent = 424.

On heating at 95° the acid lost 13.3% by weight. Calculated for $C_{19}H_{12}O_2NBr$, C_3H_6O , acetone = 13.7%.

Japp and Murray [*J.C.S.* (1894), 65, 891] have described several derivatives of indole which crystallise from acetone with solvent of crystallisation.

The acetone of crystallisation was removed from the acid A' by heating at 100° until constant weight. The acid then melted at $229-230^\circ$.

Found N = 4.0%; acid equivalent = 359. Calculated for $C_{19}H_{12}O_2NBr$, N = 3.8%; acid equivalent = 366.

This acid resisted all attempts to prepare salts with quinine, cinchonine, quinidine, cinchonidine, strychnine and l-menthylamine.

By adding concentrated nitric acid to its solution in glacial acetic acid, and then adding water after allowing to stand for some minutes, a bright yellow solid was precipitated. It was recrystallised from methyl alcohol and then melted at 285° .

Found N = 6.7%; acid equivalent = 423. Calculated for $C_{19}H_{11}O_4N_2Br$, N = 6.8%; acid equivalent = 411.

This substance thus appeared to be a mononitro derivative of the acid A'. However, it was found that it would not give satisfactory salts with optically active bases.

The ester B on hydrolysis yielded an acid B' which was recrystallised from benzene. It then melted at 188-189°.

Found N = 3.7%; acid equivalent = 372. Calculated for $C_{19}H_{12}O_2NBr$, N = 3.8%; acid equivalent = 366.

This acid could not be made form salts with brucine, quinine, cinchonine, quinidine, cinchonidine or l-menthylamine.

When nitrated in the same way as described for the acid A' it yielded a yellow solid which after recrystallisation from methyl alcohol melted at 227°.

Found N = 6.4%; acid equivalent = 434. Calculated for $C_{19}H_{11}O_4N_2Br$, N = 6.8%; acid equivalent = 411.

The small quantity of this acid prepared did not permit a greater degree of purity being attained.

1-Methyl-3-(3':4'-dimethoxyphenyl) indole-2-carboxylic acid (XXI).

3:4-Dimethoxyphenyl pyruvic acid (13 g.) and asym. methyl phenyl hydrazine (7 g.) were dissolved in ethyl alcohol (50 c.c.). A vigorous reaction took place even in the cold. Eventually, the solution was boiled for 30 minutes. On cooling a yellow solid separated which was recrystallised from methyl alcohol and thus obtained in shining yellow prisms melting at 194°.

Found N = 4.8%; acid equivalent = 296. Calculated for $C_{18}H_{17}O_4N$, N = 4.5%; acid equivalent = 311.

The acid was fairly soluble in ethyl alcohol, benzene, chloroform and methyl alcohol, but was insoluble in ether and petroleum ether.

1-Methyl-3-(3':4'-dimethoxyphenyl) indole (XXII).

Treatment of the acid (XXI) with ethyl alcoholic hydrogen chloride led to elimination of the carboxyl

group instead of esterification. After heating for some time water was added and the solution allowed to stand when a crystalline substance was deposited. Recrystallised from methyl alcohol it was obtained in shining white plates melting at 104° .

Found N = 5.4%; calculated for $C_{17}H_{17}O_2N$, N = 5.2%.

A solution of the substance in alcohol had a purple fluorescence. It was soluble in carbon tetrachloride and glacial acetic acid, and gave no reaction for acids.

Treated in glacial acetic acid with concentrated nitric acid it gave rise to a dark yellow nitro compound which after recrystallisation from alcohol melted at 166° .

Found N = 11.5%; calculated for $C_{17}H_{15}O_6N_3$ (dinitro-compound), N = 11.8%.

Department of Organic Chemistry.

The University of Sydney.

ZIERONE.

By A. E. BRADFIELD, Ph.D.,

*Lecturer in Chemistry, University College of
North Wales, Bangor,*

A. R. PENFOLD, F.A.C.I.,

Curator, Technological Museum, Sydney,

and J. L. SIMONSEN, D.Sc., F.I.C., F.R.S.,

*Professor of Chemistry, University College of
North Wales, Bangor.*

(Read before the Royal Society of New South Wales, July 5, 1933.)

Some years ago one of us (Penfold, *J. Proc. Roy. Soc. N.S.W.*, 1926, 60, 104) separated from the essential oil of *Zieria macrophylla* (Bonpland) a cyclic ketone, zierone. Analysis of the ketone (and of the semicarbazone) appeared to show that it was isomeric with irone and that it had the formula $C_{13}H_{20}O$. A reconsideration of its physical constants suggested to us that this formula was incorrect, and we have therefore made a further study of the ketone. Although the analytical figures (see p. 202) for a new specimen of a ketone, which had been regenerated from its semicarbazone by hydrolysis with oxalic acid and distillation in steam, gave figures in fair accord with those previously recorded, the analysis of the semicarbazone and of the 2:4-dinitrophenylhydrazone have shown conclusively that zierone cannot have the formula previously assigned to it, but that it must be a sesquiterpene ketone, $C_{15}H_{22}O$, isomeric with eremophilone (*J.C.S.*, 1932, 2744; *J. Proc. Roy. Soc. N.S.W.*, 1932, 66, 420). It may be noted that

satisfactory analytical figures could not be obtained for this ketone and seems to us probable that slight oxidation or hydration occurs during the prolonged steam distillation involved in the regeneration of these ketones from their semicarbazones and the impurity so introduced cannot later be eliminated.

Partly owing to the difficulty in obtaining the ketone in sufficient quantity, we have not succeeded in determining its constitution, but we consider it to be tricyclic with one ethylenic linkage for the following reasons: (i) titration with benzoylhydroperoxide shows the presence of only one double bond; (ii) reduction with sodium and alcohol results in the formation of an alcohol, *zierol*, $C_{15}H_{24}O$, from which zierone can be regenerated by oxidation with chromic acid; (iii) on catalytic hydrogenation approximately two molecules of hydrogen are absorbed, but the product is a mixture containing hydrocarbon, so that addition does not occur only at the ethylenic linkage.

Zierone has a $-CH_2$ group adjacent to the carbonyl group as it yields a liquid hydroxymethylene derivative, characterised by the preparation of a crystalline 2:4-*dinitrophenylhydrazone*, m.p. 155–157°. The ethylenic linkage is not in the $\alpha\beta$ - position to the carbonyl group since it is not reduced by sodium in ethyl alcoholic solution, and in agreement with this is the fact that the ketone is not oxidised by hydrogen peroxide in the presence of alkali. The ethylenic linkage is almost certainly present as a part of a ring system as on ozonolysis only traces of formaldehyde and no acetone are formed. Unfortunately, the decomposition products of the ozonide did not lend themselves to purification. Zierone is remarkably resistant to oxidation with

O—July 5, 1933.

potassium permanganate, and this agrees well with the suggestion that it is tricyclic.

The dehydrogenation with selenium of the hydrocarbon obtained by the dehydration of zierol yields an "azulene" resembling in its properties the Se-guaiazulene prepared by Ruzicka and Haagen-Smith (*Helv. Chim. Acta*, 1931, 14, 1104) from the hydrocarbon guaiane. The determination of the structure of this azulene would probably throw light on that of zierone. The molecular refraction of the ketone, $[R_L]_D = 66.93$, is high, and suggests conjugation of a cyclopropane ring both with the ethylenic linkage and the carbonyl group.

EXPERIMENTAL.

The ketone was purified through its semicarbazone (see below) from which it was regenerated by hydrolysis with oxalic acid and distillation in steam. The freshly distilled ketone, b.p. $147-149^\circ/18$ mm., was a somewhat viscid, colourless oil, which became yellow on keeping. Analysis showed it to be impure.

3.56 mgm. gave 10.54 mgm. CO_2 and 2.98 mgm. H_2O .
C = 80.8, H = 9.3.

3.67 mgm. gave 10.90 mgm. CO_2 and 3.12 mgm. H_2O .
C = 80.9, H = 9.4.

$\text{C}_{15}\text{H}_{22}\text{O}$ requires C = 82.6, H = 10.1%.

Zierone is not attacked by hydrogen peroxide in alkaline solution, whilst in acetone solution it was stable to potassium permanganate even on boiling. When treated with benzoylhydroperoxide in chloroform solution 0.66 atom of oxygen was taken up in one day at 2° ; after two days 0.91 atom and after seven days 0.95 atom had been taken up. Zierone did not react with maleic anhydride, whilst with hydrogen bromide it gave an extremely unstable hydrobromide.

The semicarbazone crystallised from methyl alcohol in prisms, m.p. 182°.

4.085 mgm. gave 10.42 mgm. CO_2 and 3.485 mgm. H_2O .

C = 69.5, H = 9.5.

4.97 mgm. gave 12.73 mgm. CO_2 and 4.185 mgm. H_2O .

C = 69.8, H = 9.4.

$\text{C}_{16}\text{H}_{25}\text{ON}_3$ requires C = 69.8, H = 9.1%.

The 2:4-dinitrophenylhydrazone crystallised from alcohol in glistening terracotta needles, m.p. 95–97°.

3.50 mgm. gave 8.175 mgm. CO_2 and 2.07 mgm. H_2O .

C = 63.7, H = 6.6.

$\text{C}_{21}\text{H}_{26}\text{O}_4\text{N}_4$ requires C = 63.6, H = 6.6%.

Reduction of Zierone.

(i) *Catalytic.* The ketone (6.7 g.) in ethyl alcohol (20 c.c.) containing Pd-norite (1 g.; Pd 10%) was shaken with hydrogen when 1,400 c.c. (1.93 moles.) were absorbed. After filtration the alcohol was removed by distillation, the residual oil dissolved in ether, the ethereal solution dried and evaporated. The oil so obtained distilled irregularly from 110–145°/15 mm. and it only reacted partially with semicarbazide acetate yielding a gummy semicarbazone. The oxime was an oil. As mentioned on p. 204, the hydrogenation product contained some hydrocarbon, but we were not successful in separating a homogeneous product.

(ii) *With Sodium and Ethyl Alcohol.* Zierol. The ketone (12 g.) in ethyl alcohol (400 c.c.) was treated in boiling solution with sodium (40 g.). After solution of the sodium was complete the ethyl alcohol was removed in steam, the reduction product dissolved in ether, the ethereal solution dried over potassium carbonate and the solvent removed.

The residual oil distilled at 151–152°/17 mm., n_D^{20} 1.5094, $[\alpha]_{5461} + 37.4^\circ$ (in methyl alcohol, $c = 8.5$).

3.42 mgm. gave 10.25 mgm. CO_2 and 3.48 mgm. H_2O .

C = 81.7, H = 11.4.

3.39 mgm. gave 10.15 mgm. CO_2 and 3.37 mgm. H_2O .

C = 81.6, H = 11.1.

$\text{C}_{15}\text{H}_{24}\text{O}$ requires C = 81.8, H = 10.9%.

Zierol was a colourless viscid oil, which did not yield any crystalline derivatives. On oxidation with chromic acid in acetic acid solution *zierone* was regenerated (semicarbazone, m.p. 182°).

Hydroxymethylene-zierone.

To a well cooled solution of the ketone (5 g.) in ether (50 c.c.) containing finely divided sodium (0.58 g.) in suspension amyl formate (3 g.) was gradually added. The sodium slowly dissolved and after standing overnight ice was added to the yellow ethereal solution. The brown alkaline layer was separated, extracted twice with ether to remove neutral products and made just acid with acetic acid, when an oil separated. This was dissolved in ether, the ether separated, dried and evaporated when a viscid oil (3 g.) remained. It gave in alcoholic solution an intense purple coloration with ferric chloride. As hydroxymethylene-zierone did not crystallise, it was converted into the 2:4-dinitrophenylhydrazone, which separated from alcohol in brown plates, frequently twinned, m.p. 155–157°.

3.67 mgm. gave 8.38 mgm. CO_2 and 2.0 mgm. H_2O .

C = 62.3, H = 6.1.

3.959 mgm. gave 9.01 mgm. CO_2 and 2.05 mgm. H_2O .

C = 62.0, H = 5.8.

$\text{C}_{22}\text{H}_{26}\text{O}_5\text{N}_4$ requires C = 62.0, H = 6.1%.

Dehydrogenation of Zierol.

Zierol was dehydrated by digestion with formic acid, and the resulting hydrocarbon (7 g.) was heated with selenium (11 g.) at 250–280° for forty-four hours. Extraction with ether gave a violet coloured oil, b.p. 135–165°/15 mm. This was dissolved in three times its volume of ligroin (40–60°) and gently shaken with phosphoric acid (d. 1.7). The phosphoric acid layer acquired a reddish-brown colour, whilst the ligroin became brownish-yellow. The phosphoric acid solution was separated, treated with crushed ice and the violet oil which separated was dissolved in ether, the ethereal solution washed with sodium hydroxide solution, water, dried and the ether evaporated. The residual oil was dissolved in alcohol and mixed with a hot alcoholic solution of picric acid when, on standing, black needles of azulene picrate, m.p. 110–111°, were deposited (compare Ruzicka and Haagen-Smit, *loc. cit.*). The quantity of picrate obtained was insufficient for complete purification and identification. The ligroin solution (see above) gave on evaporation an oil which did not yield a crystalline picrate.

Our thanks are due to Professor Heilbron, D.S.O., F.R.S., for kindly having the oxidation with benzoylhydroperoxide carried out in his laboratory and to the Government Grants Committee of the Royal Society and to Imperial Chemical Industries for grants which have in part defrayed the cost of this investigation.

THE DEVONIAN STRATA OF THE KANDOS
DISTRICT, NEW SOUTH WALES.

By C. A. SUSSMILCH, F.G.S.

(With One Text-figure.)

(Read before the Royal Society of New South Wales, August 2, 1933.)

This paper describes the geological features of an area which occurs in the Parish of Wells, County of Roxburgh, New South Wales, and lies immediately to the west of the township of Kandos; the Sydney-Mudgee railway line lies along its eastern margin. The only previous reference to the geology of this area occurs in the descriptions of the limestones of New South Wales by J. E. Carne and L. J. Jones.¹ In this work the limestones of the Kandos district are mapped and briefly described and are stated to be of Devonian Age. No lists of fossils are given and the associated strata are only referred to very briefly. The limestones which occur here are very extensive and are being quarried on a large scale for use in cement making by the two companies operating at Charbon and Kandos respectively.

GENERAL GEOLOGY.

The following formations are represented in the district:

Cainozoic Era—Pliocene Period, Basalts.

Mesozoic Era—Triassic Period, the Hawkesbury-Narrabeen Sandstones.

Palæozoic Era—

Permian Period—

Upper or Lithgow Coal Measures.

Upper Marine Series.

¹ "The Limestone Deposits of N. S. Wales", by J. E. Carne, F.G.S., and L. J. Jones, A.S.T.C. Mineral Resources, No. 25. Dept. of Mines, N. S. Wales, 1919.

Devonian Period—

Upper Devonian (Mt. Lambie Series).

Middle Devonian (Kandos Series).

The Tertiary basalts are limited to a small area on top of Cumbermelon Mountain, which lies outside of and just to the east of the Parish of Wells. The Hawkesbury-Narrabeen Series and the Upper Coal Measures, although they at one time extended across the whole of the Parish of Wells, have been entirely removed by denudation since the uplift which produced the present tablelands. They, however, still survive in Cumbermelon Mountain already referred to. These formations have been fully described in Mr. J. E. Carne's monograph on the Western Coalfield of New South Wales.²

The Upper Marine Series in Cumbermelon Mountain has a thickness of about 400 feet; the upper part consists mainly of soft shales, and the lower part of conglomerates. The shales are being quarried by the Kandos Cement Company and used in their cement works, but over most of the district these beds have been removed along with the Upper Coal measures. The basal conglomerates, however, still survive over much of the Parish of Wells as an almost horizontal bed from 50 feet to 150 feet in thickness capping the underlying folded Devonian strata. Along all of the main stream channels this layer of Permian conglomerate has been cut through and the underlying Devonian strata exposed. An interesting feature of these Permian conglomerates is the evidence they afford of the existence of glacial conditions in this

² "The Geology and Mineral Resources of the Western Coalfield", by J. E. Carne, F.G.S. Memoir No. 6. Geological Survey of N. S. Wales, 1908.

region in Permian times. These beds were deposited on the sea floor only a few miles away from the Permian land surface and the shore line of this land was made up very largely of massive Upper Devonian quartzite. Many large boulders of this quartzite, some of them crowded with Devonian fossils, occur in the Upper Marine conglomerates, not only at the base but at various horizons from 50 feet to 150 feet above the base, and they occur not only in the conglomerates themselves, but also in the beds of fine-grained sandstones and sandy shales interstratified with the conglomerates. These boulders range up to 6 feet or more in diameter. Occasionally one finds a relatively flat boulder standing on edge in the fine-grained strata. It would appear to be more than probable that these boulders had been transported by floating ice and that as the ice melted, the boulders were dropped on to the sea bottom; the ice would have been derived either from glaciers on the neighbouring land or from sea ice frozen on to the shore in winter time and breaking off and floating away in summer time. These beds, therefore, might be correlated with the Muree glacial horizon of the Upper Marine Series of the Hunter River district.

The Devonian Formations.

The main object of this paper is to describe the Devonian formations which occur extensively in this district. Both from their lithological and palæontological characteristics they fall naturally into two divisions: (*a*) a lower division of Middle Devonian Age, which it is proposed to call the Kandos Series; and (*b*) an upper division of Upper Devonian Age, which is considered to be the equivalent of the Mt. Lambie Series.

The former consists dominantly of limestones, clay stones and tuffs, while the latter consists dominantly of quartzites with a few small limestone beds. The two series of strata, therefore, were deposited under somewhat different conditions. The field evidence indicates that the two formations are conformable to one another, the Middle Devonian series passing upwards into the Upper Devonian series without any angular unconformity and the change in the nature of the sediments at the junction is not an abrupt one, there being a gradual interstratification of the claystones of the lower series with the quartzites of the upper series. Both series have been subjected to the same epoch of folding (the Kanimbla Epoch), during which both were intruded by the same series of quartz porphyries and felsites. The main structural feature of the area is a large symmetrical anticline striking about N. 25° W. with the Kandos series outcropping in the axis of the anticline and the Mt. Lambie series outcropping on both the eastern and western limb; there is considerable minor folding superimposed upon the main anticline.

A. *The Kandos Series.*

This series consists of limestones, claystones, tuffs and conglomerates with a total thickness of upwards of 4,000 feet. As the base of the formation has nowhere been seen, the thickness may be considerably greater. Good outcrops occur along the road from Rylstone to Cudgong and along Carwell Creek from the Charbon quarry northwards to where this creek crosses the Cudgong road. The lower part of the following detailed section was obtained from the Cudgong road, while the upper part was obtained from Carwell Creek, going westwards from the Kandos quarry.

MIDDLE DEVONIAN SECTION.

| | Approximate Thickness. Feet. |
|--|------------------------------------|
| Claystones with some thin beds of quartzite .. | 1,650 |
| Acid tuffs | 20 |
| Claystones | 20 |
| Quarry limestone (No. 3 limestone bed) .. | 200-400 |
| Limestone breccia | 250 |
| Claystones (siliceous) | 300 |
| Limestone (No. 2 bed) | 100 |
| Claystones | 350 |
| Conglomerates | 50 |
| Limestones (No. 1 bed) | 30 |
| Tuffs | 40 |
| Black cherts | 20 |
| Conglomerates | 40 |
| Tuffs | 750 |
| Total | <hr/> 4,320 <hr/> |

(a) The Tuffs.

These occur mainly at the base of the section and are well exposed on the Cudgegong road on portions 59, 72 and 74, Parish of Wells. At their base there is an intrusive contact with the quartz porphyry to be described later, so that the true base of the series is not exposed. These tuffs are very fine-grained and are sub-acidic in character, containing quartz and felspar, the latter much decomposed. They also contain occasional fragments of other rocks such as quartzite, slate, etc. Higher up in the series, just above the No. 3 limestone bed, there is a coarse tuff crowded with broken crystals of quartz and felspar, the former being very abundant, so that the rock is highly acidic. It contains very much secondary calcite not only in the ground mass but in the cracks in the quartz and felspar crystals.

(b) The Black Chert.

This is a dense, fine-grained black rock with no noticeable bedding planes and resembles somewhat the typical Radiolarian cherts of the Tamworth district and also

those of the Jenolan Caves district. No Radiolaria, however, have yet been identified. The only outcrop seen, which is quite small, occurs on portion 73 and is limited to the creek bed, but the occurrence of abundant pebbles of a similar rock over a wide area in the basal conglomerates of the Upper Marine Series suggests the possible existence of a considerable thickness of this formation concealed under the Permian strata.

(c) *The Conglomerates.*

These outcrop strongly in portion 73 in the bed of a creek which flows parallel to and immediately to the north of the Cudgegong road. The pebbles are small, averaging less than 1 inch in diameter, but with occasional larger pebbles up to 3 inches in diameter. The pebbles consist mainly of a black chert rock similar to that just described. Reference to the section already given will show that these conglomerates occur below as well as above the chert bed referred to. These conglomerates appear to be quite local and apparently thin out quickly along the line of strike.

(d) *The Claystones.*

The claystones in the lower part of the section, that is below the quarry limestones, are thin bedded and highly siliceous and have been subjected to a limited amount of metamorphism. They outcrop extensively on portions 65 and 71. In this region careful search failed to reveal any fossils. A similar series of strata, however, occurs to the west of the area described on portion 118 of the Parish of Dungeree about a mile east of the village of Cudgegong, and also stratigraphically below the very thick Cudgegong limestone bed considered by the author to be the equivalent of the Quarry limestone. On the bank
PP—August 2, 1933.

of the Cudgegong River, just east of the junction of Yellowman's Gully with this river, there occurs in this series a bed of shale about 4 feet in thickness crowded with fossil Brachiopods. The fossils obtained from this locality have been determined by Mr. W. S. Dun as follows:

Bryozoa—*Monticuliporoid*, Indet.

Brachiopoda—

Orthotetes, sp. nov. (cf. *desiderata*).

Chonetes (cf. *hardrensis*).

Camarotæchia (cf. *Rhynchonella pleuroden*).

Rhynchonellid (cf. *R. pugnus*).

Pelecypoda—

(*Actinopteria* sp. nov.)

Orthonota.

This fauna is considered by Mr. Dun to be of Middle Devonian Age. The claystones which occur above the Quarry limestone are somewhat tuffaceous and contain occasional thin beds of quartzite, but have so far yielded no recognisable fossils. They appear to merge upwards into the quartzites of the Mt. Lambie series.

(e) *The Limestones.*

The limestones occur approximately in the middle of the series and are both thick and persistent. The top-most bed is here called the Quarry limestone and in it are the extensive quarries for the Kandos and Charbon Cement Works. It outcrops extensively along Carwell Creek and its outcrop can be traced continuously from the Charbon quarries in portion 131 northwards to the Cudgegong road where it disappears under the alluvium of Carwell Creek, a total distance along the line of strike of nearly $2\frac{3}{4}$ miles. At its southern end it is cut off abruptly by an intrusion of quartz-porphyry. Its

SKETCH SECTION ACROSS CARWELL CREEK ANTICLINE AT RIGHT ANGLES TO THE STRIKE

Horizontal Scale
0 30 60
1 inch = 20 chains

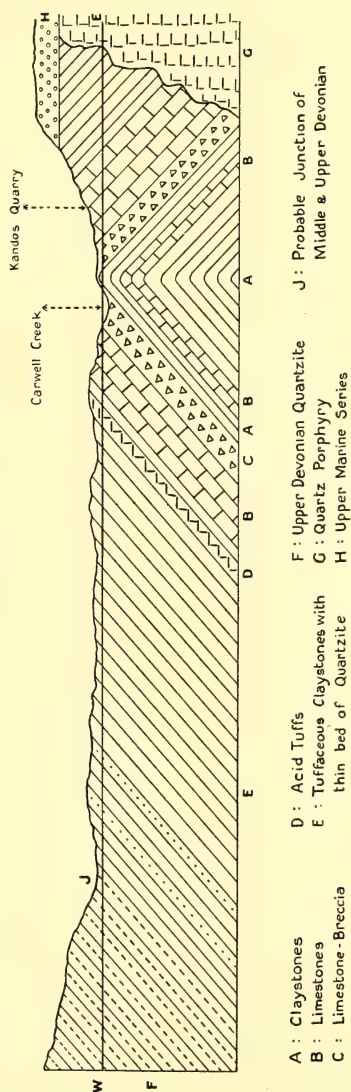


Fig. 1.

thickness along this length varies from 200 feet to 400 feet and its direction of strike is about N. 25° W. At the Kandos quarries this bed is seen to be folded into a definite anticline, the continuous outcrop above described being the western leg, and it is this leg which is being worked in the Charbon quarries. The Kandos quarries are situated in the eastern leg of the anticline, which here has a very wide outcrop owing to a minor syncline being superimposed on the major anticline. This syncline is well shown on the quarry face. The limestone in the eastern leg of the anticline has no great extent along the line of strike, being cut off at both ends by intrusive quartz-porphry.

The Quarry limestone has in general a blue-black colour and is very pure, but is definitely bedded, the bedding planes being well shown in the quarry face. A traverse across the weathered outcrop displays abundant fossils, mostly corals, the species varying somewhat from bed to bed. The fossils, unfortunately, although very abundant, are not very well preserved. A few fossils have also been found in the shales immediately overlying the limestone. Mr. W. S. Dun has determined the following genera and species:

Hydrozoa—

Amphipora (2 species).

Stromotoporella (2 species, 1 apparently new).

Actinozoa—

Cyathophyllum sp. nov. (cf. *C. Mitchellii*).

Cyathophyllum sp. Ind. (simple form).

Tryplasma, several species, one of Liliiform type.

Favosites (Dendroid forms, 2 species).

Favosites (massive form), Goldfussi type.

Pachypora Meridionalis.

Pachypora sp. nov.

Syringopora (?) *speleanus.*

Brachiopoda (?) *Orthis* (?) *Arcuata* type).

Pelecypoda—*Orthonota* sp.

Cephalododa—*Orthoceras* sp.

Trilobita—*Proetus* sp.

This fossil fauna is considered by Mr. W. S. Dun to be of Middle Devonian Age.

The No. 2 limestone is quite different in character from the Quarry limestone and varies from white to pink in colour, the only fossils found being a massive *Favosites*. It outcrops on the side of the Cudgegong road on portion 151 and can be traced northwards for a distance of about 30 chains. It has a thickness of about 100 feet and dips westerly at an angle of about 39°. The No. 1 limestone bed occurs as a small outcrop in portion 73, but this outcrop could not be traced for any distance.

(f) *The Limestone Breccias.*

Just below the Quarry limestone there is an interesting rock containing an abundance of angular fragments of limestone and claystone. Its occurrence beneath the limestone is a very persistent one and its actual origin is somewhat obscure.

The contact between the Middle Devonian and Upper Devonian Series is usually very obscure owing to the fact that the claystones in the upper part of the older series are readily weathered and eroded and the junction is therefore usually a creek channel filled with detritus. One contact has been observed, however, where Carwell Creek traverses portions 109 and 90, which shows the

gradual passage of the claystones of the lower series into the quartzites of the upper series. Further to the west some of the junctions between the two formations are undoubtedly fault junctions.

B. *The Mt. Lambie Series.*

This consists mainly of quartzites but includes some thin beds of claystone and occasional thin beds of limestone. They outcrop very strongly on the western side of the anticline along the western part of the Parish of Wells, as well as in the adjoining Parish of Bocoble, where they form a series of rugged hills lying immediately to the west of Carwell Creek. Where the Cudgegong road cuts through these hills there are many road cuttings which give good sections, particularly for the last few miles before the road reaches the village of Cudgegong. Here the series is found to consist almost entirely of quartzites folded into a series of anticlines and synclines and displays much faulting. In one of these cuttings a bed of limestone about 1 foot thick was seen interstratified with the quartzites but without any fossils. Some thin beds of shale also occur here, one of which was found to be crowded with poorly preserved fossils, mainly Brachiopods and small branching corals. On one horizon also the quartzites over a thickness of at least 30 feet were found to be crowded with the casts of crinoid stems.

On the eastern side of the anticline the outcrops of the Mt. Lambie Series are largely covered by the Upper Marine conglomerates, but where the aerial tramway of the Charbon quarries crosses Cumbermelon Creek good outcrops occur both along the main creek channel and along some of its tributaries. Here also the strata consist mainly of massive quartzites and these are well

shown in the creek channel immediately below the Charbon dam. Along the main channel of Cumbermelon Creek south of the Charbon tramway there is a very persistent bed of limestone ranging up to 30 feet in thickness with quartzites both above and below it. This limestone is dolomitic and has been extensively quarried along the course of the creek. Its junction with the underlying quartzites has formed a line of weakness and Cumbermelon Creek has cut out its channel along this junction for a distance of a mile or more. Fossils in this bed of limestone are rare and are poorly preserved and consist mainly of massive *Favosites* and a simple form of *Cyathophyllum*.

The fossils found in the Mt. Lambie series of the Kandos district have been determined by Mr. W. S. Dun as follows:

Actinozoa—*Favosites*, both branching and massive forms.

Crinoidea—Crinoid stems.

Bryozoa—*Monticuliporoid* indet.

Brachiopoda—

Spirifer disjunctus.

Rhynchonella (? *Camarotæchia*).

(?) *Orthotetes*.

Some of the large quartzite boulders found in the Upper Marine conglomerates and obviously derived from the Mt. Lambie series contain an abundance of fossils, particularly *Spirifer disjunctus* and *Rhynchonella pleuroden*. No doubt the horizons from which these boulders were derived will ultimately be found *in situ*.

Both the lithological characters of the strata and the contained fossils show fairly conclusively that this series

can be correlated with what has been called the Mt. Lambie series occurring at Rydal some miles to the south.

As the top of the series has not yet been located and as the strata have been extensively folded and faulted, it has been impossible to determine the true thickness, but this thickness is at least several thousands of feet.

The Middle Devonian formation of the Kandos district appears to form part of a great belt which extends northwards at least as far as the Mudgee district and southwards through the Capertee Valley; the Devonian strata of this latter locality have been mapped by the late J. E. Carne. His description of them, however, is only very brief and no attempt appears to have been made to decide as to which part of the Devonian period the strata belong; apparently both Middle and Upper Devonian strata are represented, as recently Mr. W. L. Waterhouse has collected from the Blue Rock limestone of the Capertee Valley the typical Middle Devonian fossil sponge *Receptaculites australis* associated with one of the Kandos fossil corals, *Syringopora speleana*. At the southern margin of the Capertee Valley these beds disappear under the younger strata of the Blue Mountain tableland.

The Upper Devonian strata extend practically without a break southwards to the Kanimbla Valley at Hartley where this belt also disappears beneath the younger strata of the Blue Mountain tableland.

The Quartz Porphyries and Felsites.

These outcrop extensively in the eastern part of the area, especially along the valley of Cumbermelon Creek from the Charbon aerial tramway northwards to the junction of this creek with the Cudgegong river. These

igneous rocks are intrusive into both the Middle and Upper Devonian strata and intrusive contacts can be seen at quite a number of localities. The fresh rock has a dark blue to bluish-grey colour but on weathering becomes a dull white; in some localities it shows an abundance of small phenocrysts of quartz and felspar, but at other places phenocrysts are almost entirely absent. Quite probably there have been two intrusions, an earlier one of quartz porphyry and a later one of quartz felsite as at several places near the margin of the intrusion angular fragments of the porphoritic phase may be seen as angular inclusions in the felsitic phase.

The latter in places displays a well-marked flow structure, but this feature appears to be quite local.

Under the microscope the rock displays a cryptocrystalline to glassy ground mass which in some slides exhibits flow structures. The phenocrysts include quartz, orthoclase, plagioclase, a little biotite and an occasional flake of muscovite. In some microslides the mineral chlorite is seen replacing both the plagioclase and the biotite. At one locality, where the Kandos aerial tramway crosses Cumbermelon Creek, the quartz porphyry exhibits a very unusual nodular structure; the nodules are so large and abundant that when viewed from only a short distance the rock looks like a conglomerate. The nodules are rudely spherical, ranging from $1\frac{1}{2}$ inches to 4 inches in diameter, and are found to contain segregations of Chalcedonic silica. In some of the nodules the silica is segregated in the centre, but in other cases it forms curved concentric layers at the margin of the nodule.

The origin of the silica is not quite clear. If it had been produced by weathering processes one would expect it to be much more widespread than it is; it is quite possible that the silica is magmatic and that its segregation was due to deuteric action. As has been already stated, the quartz porphyry and felsite intrude the Devonian strata but they do not intrude the overlying Upper Marine series, the latter resting upon a denuded surface of the igneous rocks and containing water-worn pebbles of them. These intrusions belong to what the author has previously described as the Kanimbla epoch, which is either of Late Devonian or Early Carboniferous Age.

GEOLOGICAL HISTORY.

During the Devonian period this part of New South Wales was covered by the sea and was undergoing a slow subsidence which ultimately allowed of the deposition of upwards of 6,000 feet of marine strata. During the Middle Devonian epoch this sea was a shallow one, but was sufficiently far from a shore line to receive, for the most part, only the finer grained terrigenous sediments, while for considerable periods the water was so free from such sediments as to allow of the development of extensive coral reefs with the ultimate accumulation of very thick beds of pure limestone. That contemporaneous volcanic activity was taking place is indicated by the tuffaceous nature of some of the strata.

In the Upper Devonian epoch, owing either to some climatic change or to an advance of the shore line, deposition took place, on a large scale, of coarser sediments, but even during this epoch the deposition of these coarse sediments temporarily ceased at times and limestone making conditions were resumed.

The Devonian period was closed by a great orogenic earth-movement (the Kanimbla Epoch), as a result of which the Devonian strata were strongly folded and the whole region uplifted above sea level. This folding was accompanied by the intrusion in the Kandos district of quartz porphyries and felsites, while some little distance to the south in the Capertee Valley and in the Kanimbla Valley extensive intrusions of granite also took place.

The Kanimbla Epoch of earth-movement was followed by a long cycle of erosion which extended throughout the Carboniferous period and well into the Permian period, as a result of which a remarkably well developed peneplain was cut out of the folded Devonian strata and their associated igneous rocks; it is advisable that this peneplain should have a name and it is suggested that it be called the Capertee peneplain, as it has now been extensively re-exposed in the Capertee Valley region by present-day processes of denudation. In Permian times, during the Upper Marine epoch, the sea again transgressed the land in this region and Upper Marine strata were deposited on the surface of the Capertee peneplain. The occurrences of large erratics in these strata suggest the existence of glacial conditions at this time. The cutting off of the sea at the close of the Upper Marine epoch converted the region into a freshwater lake in which the Upper Coal Measures and the Triassic formations were deposited. Since that time the region has apparently remained dry land and at the close of the Cainozoic Era a great epeirogenic uplift took place which produced the present tablelands some 3,000 feet in altitude. The denudation which followed this uplift has now re-exposed over large areas the old Capertee peneplain by the stripping away of the overlying strata along

Q—August 2, 1933.

the line of the weak shales of the Upper Marine Series and Upper Coal Measures, and the present-day streams are now entrenching themselves in deep gorges cut below the surface of this old peneplain. These physiographical features will be described in more detail in a later paper.

AN INTERFERENCE METHOD OF DETERMINING INDICES OF REFRACTION IN THE INFRA-RED.

By H. J. FROST, M.Sc.

(With Two Text-figures.)

(Read before the Royal Society of New South Wales, Sept. 6, 1933.)

An interference method is described for determining the dispersion curve in the infra-red of a material in the form of thin sheets. Tested with mica it was found that the index of refraction could be determined to a precision of 1 in 500 up to $\lambda = 6\mu$.

The method consisted of the application in the infra-red of a procedure adopted by Vonwiller and Arnot (*Proc. 3rd Pan-Pac. Sc. Congress*, 1926, p. 1314) in the visible region.

When a parallel beam of white light is incident on a thin sheet of material, the spectrum of the transmitted light examined in a spectroscope shows sharp maxima if the angle of incidence is nearly 90° , enabling the wavelengths of the maxima to be determined with relatively high precision.

The condition for a maximum is

$$p\lambda = 2t(n^2 - \sin^2 i)^{\frac{1}{2}} \dots \dots \dots (1)$$

where "p" is an integer (the "order" of the maximum), " λ " its wave-length, "n" the index of refraction of the material, "t" the thickness of the plate, and "i" the angle of incidence of the beam of light on the plate.

One cannot assume $p_1\lambda_1 = p_2\lambda_2$, as "n" is not constant; but Vonwiller and Arnot have shown that, with mica, in the visible region one may assume Cauchy's formula

$$n^2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \dots$$

$$\text{so that } p\lambda = A' + \frac{B'}{\lambda^2} + \frac{C'}{\lambda^4} + \dots$$

They have also shown that it is necessary to use only two terms of the expansion to determine "p" without ambiguity, so that the wave-lengths of three bands (or maxima), known numbers of bands apart, are necessary to determine "p". If p, p+r, and p+s are the orders of the three bands, then a more convenient form of the formula is

$$\frac{p(\lambda_1 - \lambda_2) - r\lambda_2}{p(\lambda_1 - \lambda_3) - s\lambda_3} = \frac{(\lambda_1 - \lambda_2)(\lambda_1 + \lambda_2)\lambda_3^2}{(\lambda_1 - \lambda_3)(\lambda_1 + \lambda_3)\lambda_2^2} \dots \dots (2)$$

This was found to give very satisfactory results in the infra-red as well as in the visible.

A value of "p" having been obtained, there are still two unknowns in equation (1), namely, "n" and "t". In the visible these may be determined in the following manner: The cross-hair in the eye-piece of the spectrometer is set on one of the bands and then the sheet of the material is rotated through a known angle, the number of bands passing the cross-hair being noted, photographs being taken in the initial and final positions, enabling the fractional part of the order of the band to be determined precisely. Then we have

$$p\lambda = 2t(n^2 - \sin^2 i_1)^{\frac{1}{2}} \dots \dots \dots (3)$$

$$(p+q)\lambda = 2t(n^2 - \sin^2 i_2)^{\frac{1}{2}} \dots \dots \dots (4)$$

p and q being integers corrected by the fractions determined by the photographic measurements. From (2) and (3), the value of "n" for the particular wave-length

employed may be calculated and also the value of "t". By substituting the value of "t" in equation (1), the value of "n" for each of the wave-lengths for which a maximum occurs may be calculated.

In applying the method to the examination of a sheet of mica in the infra-red, it was found that the positions of the maxima could be determined with an error of less than 100 Å. (0.01μ) with a sheet of mica of thickness 6.06μ (6.06×10^{-4} cm.). The positions of the bands are given in the table at the end.

With this sheet it was possible, by applying equation (2), to determine "p" without ambiguity. The value of "t" could have been determined by using in the infra-red the method indicated above, but it could be found more accurately in the visible by following the above method precisely. The value of "t" quoted is accurate to at least 1 in 500, which was sufficient in view of the limited accuracy caused by the uncertainty in the position of the maxima, but it could have been found more accurately if it had been necessary.

The above theory is worked out for a parallel beam of light, but, in practice, the beam used was convergent, the mica sheet being held just in front of the collimator slit. The cone of light had an angle of about $\frac{1}{14}$ and it was calculated that, for large angles of incidence, such as were used (about 85°), the effect of the convergence of the beam on the sharpness of the bands was negligible.

The infra-red spectrometer employed was a Hilger D₃₅ instrument, using a Hilger thermopile and a Moll thermal relay for the measurement of the heat energy.

Since mica is doubly-refracting, a polariser of some sort was necessary. The polariser used was one designed by Miss Nicol, of Sydney University. It was similar to

the type designed by Pfund, using a selenium plate at the polarising angle, but had only two silver plates instead of three as in Pfund's. The polariser was set so that the electric vector was perpendicular to the plane of incidence of the light on the mica sheet, this arrangement giving the sharper bands.

It was found that the thermopile was affected by the opening or closing of doors in the neighbourhood, or by winds, this being due to the adiabatic heating and cooling accompanying small compressions and rarefactions of the air round the thermopile. Hence it was necessary that the thermopile should be completely sealed. This was done by sealing the thermopile slit with a thin sheet of mica and by waxing the thermopile cover to make it airtight. A device was included whereby the width of the slit could be varied without unsealing the thermopile.

The prism used was the one supplied with the spectrometer and consisted of rocksalt. Since the temperature coefficient of the index of refraction of rocksalt is high, it was necessary to correct for the temperature. It should be noted that in the list of refractive indices supplied by the makers the refractive indices are not all given at one fixed temperature, but at different temperatures varying from about 14.5° C. to 19.5° C.. Since the wave-length drum of the spectrometer had been calibrated using the above values of the indices of refraction, the drum was recalibrated from a knowledge of the index of refraction of rocksalt, and rotations of the prism table of the spectrometer as measured by a telescope and scale, the image of the scale being viewed in the eye-piece of the telescope after reflection from the surface of a plane mirror set up at the centre of rotation of the prism table. By this means wave-lengths could be determined to 0.01μ .

The source of radiation employed was a Nernst filament rated at 100 volts and 1 ampere, the current used being usually in the vicinity of 0.5 or 0.6 ampere. In order to avoid errors due to the large variations in the emission with relatively small changes in the current, and to the "ageing" of the filament, the point-to-point method of obtaining the transmission curves was employed. The mica, held in a special clip to prevent distortion, was moved into and out of the path of the light by means of a sliding arrangement. First the reading was taken with the shutter down in front of the Nernst, then the reading with the shutter up and the mica sheet in, then the reading with the mica removed, and then the reading with the shutter down to guard against any "creep" of the zero reading. That the mica returned to exactly the same position in front of the slit was proved by repeating one reading a number of times, the results being exactly the same in every case.

The wave-lengths of the maxima of transmission were determined in two ways: firstly, by simply taking the maximum reading, and, secondly, from the meeting points of the slopes of the sides of the bands. As both methods gave the same results, the latter method was discarded in favour of the former, thus saving a considerable amount of time. Figure 1 shows the type of bands obtained and also the sharpness of the bands.

The determination was carried out in the infra-red region between 1.3μ and 6.0μ , being limited at the shorter wave-length by the emission of the filament, and at the longer wave-length by the emission of the filament combined with the increasing absorption of the mica sheet. The refractive index was also measured throughout the visible region during the process of obtaining the thickness of the mica sheet. In the region between 0.7μ

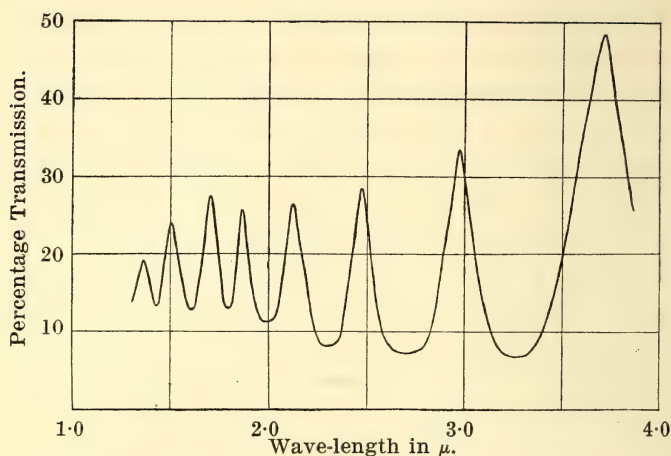


FIGURE 1.

Graph showing type of interference maxima obtained, reduced to a normal spectrum.

and 1.3μ , the refractive index was interpolated by means of Cauchy's formula from the values of A and B as found in the visible region. The results, both measured and interpolated, fitted into an even curve. It can be seen from the graph of the results obtained (Figure 2) that the dispersion curve is flattening out towards the longer wave-lengths. The values of the refractive index in the infra-red are accurate to 1 in 500 or to about 0.003 of the refractive index. It should be understood that the above work was done as a test of the possibilities of the method. The results obtained were for a single plate of mica, no note being taken of the axis used. Of course, care was taken that the same axis was used throughout the work.

J. W. Ellis (*J.O.S.A.*, Vol. 23, p. 88, 1933) describes some experiments on somewhat similar lines and uses the formula

$$N = -\left(\frac{\lambda}{\Delta\lambda}\right) \Delta N$$

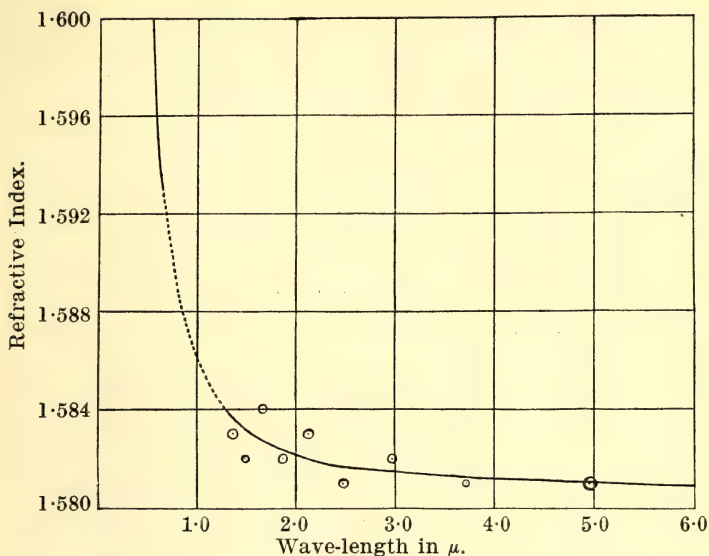


FIGURE 2.

Dispersion curve of mica. The broken line indicates the interpolated part of the curve.

for determining the order of the maxima (N). This is equivalent to assuming $p\lambda = \text{constant}$. With thin sheets of mica such as were used in the above work, this would not give accurate results and equation (2) should be used.

It is the considered opinion of the author that the above method is very well adapted for the measurement of the refractive indices of substances such as mica, which can be obtained only in thin plates. These results have been published at this stage as the author has not the opportunity of continuing the work.

In conclusion, the author wishes to take this opportunity of acknowledging the very great assistance and the excellent advice given him by Professor Vonwiller throughout the whole of the investigation.

The infra-red spectrometer and Moll thermal relay are portion of a gift of apparatus made to the Department of Physics in 1929 by G. H. Bosch, Esq..

TABLE I.—SHOWING THE WAVE-LENGTHS AND ORDERS OF THE INTERFERENCE MAXIMA AND THE CORRESPONDING INDICES OF REFRACTION.

| Order of Maximum. | Wave-Length. | Index of Refraction. |
|-------------------|---------------|----------------------|
| 3 | 4.95 μ | 1.581 |
| 4 | 3.71 μ | 1.581 |
| 5 | 2.97 μ | 1.582 |
| 6 | 2.47 μ | 1.581 |
| 7 | 2.12 μ | 1.583 |
| 8 | 1.86 μ | 1.582 |
| 9 | 1.655 μ | 1.584 |
| 10 | 1.485 μ | 1.582 |
| 11 | 1.355 μ | 1.583 |
| 23 | 0.65321 μ | 1.5925 |

THE ACTION OF NITROUS ACID ON
DIMETHYLANILINE.

PART I.

By JOHN CAMPBELL EARL, D.Sc., Ph.D.,
and ALAN WILLIAM MACKNEY.

(Read before the Royal Society of New South Wales, Sept. 6, 1933.)

In earlier papers (*This Journal*, 1932, 66, 157, 453; and *J. Chem. Soc.*, 1933, 510) the influence of small quantities of hydrochloric acid on the reaction between nitrous acid and amines has been described. In amplification of these earlier studies the behaviour of dimethylaniline with nitrous acid in the absence of stronger acids has now been investigated.

When an aqueous solution of dimethylaniline hydrochloride is introduced into a solution containing an equimolecular proportion of sodium nitrite, very little p-nitroso-dimethylaniline is formed. A product insoluble in water was isolated, which, on recrystallisation from spirit, was found to consist principally of tetramethyl benzidine. In a number of experiments using small quantities of hydrochloric acid, this substance was always formed in small quantities together with p-nitroso-dimethylaniline. In the formation of tetramethyl benzidine, nitrous acid acts, therefore, as an oxidising agent.

When a large excess of nitrous acid, prepared either by the decomposition of sodium nitrite with hydrochloric acid or by passing nitrous fumes from the action of

nitric acid on arsenious oxide into water, is allowed to act on dimethylaniline in the cold, a number of substances of considerable interest are produced. The principal among these is one decomposing at 157.8°C . (slow heating) and apparently identical with the substance obtained by Cohen and Calvert (*J. Chem. Soc.*, 1898, 73, 163) when liquefied nitrogen trioxide was introduced into an ethereal solution of dimethylaniline. It is soluble in water to a yellow solution, and sparingly soluble in most organic solvents, other than alcohol. On warming with glacial acetic acid it decomposes, as indicated by Cohen and Calvert, with the evolution of nitrous fumes.

It has not been possible, up to the present, to assign a definite structure to this substance, but its behaviour and relationships are so remarkable as to merit a description prior to their interpretation being arrived at. The percentage of nitrogen is 21.3, which corresponds to the nitrogen content of p-nitroso-dimethylaniline nitrite. It gives no reaction for a nitrite, however, and when carefully purified does not show a definitely positive reaction for the nitroso-group in the Liebermann test. On boiling with caustic soda solution it yields p-nitrosophenol and dimethylamine. It is definitely acidic

in nature, a $\frac{\text{M}}{50}$ aqueous solution having a value for p_{H}

of 3.0 when measured with the quinhydrone electrode. It is evidently closely related to p-nitroso-dimethylaniline nitrite. The last-named substance is easily formed by the interaction of nitrous acid and p-nitroso-dimethylaniline, but is unstable and readily loses nitrous acid on exposure to air. On storage of the nitrite, a certain amount of the substance under consideration is formed.

The strong yellow colour of the aqueous solutions indicates a quinonoid structure.

The decomposition by warm glacial acetic acid is amenable to control. With rapid heating, a vigorous evolution of nitrous fumes occurs, and p-nitro-dimethylaniline (m.p. 160.5° C.) is formed (*cf.* Cohen and Calvert, *loc. cit.*). When, however, the heating with acetic acid is cautiously carried out, a second substance melting at 86° C. and containing 21.5% of nitrogen is also produced. This substance shows a strong nitroso-reaction in the Liebermann test, and will be further examined.

In addition to the quinonoid substance of decomposition point 157.8° C. described above, smaller quantities of 3,3', dinitro-tetramethylbenzidine (m.p. 189° C.) and p-nitrodimethylaniline were isolated from the products of the action of excess of nitrous acid on dimethylaniline. The formation of these compounds is readily understandable. When the nitrous fumes generated from nitric acid and arsenious oxide are passed for a long time into a cooled mixture of dimethylaniline and water, considerable quantities of tetramethylbenzidine nitrate are formed. This is probably partly due to the oxidising action of nitrogen tetroxide present in the mixed gases.

The investigation is being continued.

EXPERIMENTAL.

Reaction Between Equimolecular Proportions of Nitrous Acid and Dimethylaniline.

Sodium nitrite (0.88 gram, 1 mol.) dissolved in water (15 c.c.) was added to a solution of dimethylaniline hydrochloride (2 grams, 1 mol.) in water (15 c.c.), cooled in ice, during a period of five minutes. The temperature during the addition remained below 0° C.. After the

mixture had been allowed to remain in the ice-chest for one week, the precipitate was filtered off, dried in air, and recrystallised once from methylated spirit. Yield 0.22 gram, melting at 175-182° C.. After once further recrystallising, the product melted constantly at 188° C.. N found, 11.8%; calculated for $C_{16}H_{20}N_2$, 11.7%.

The time of standing, one week, is unnecessarily long, since subsequent experiments have shown that there is little increase in the yield of crude product after the first twenty-four hours.

Several similar experiments, using the same quantities of materials, but with the addition of small quantities of hydrochloric acid, were also carried out. After the addition of the sodium nitrite to the acidified solution of methylaniline hydrochloride, the mixture was allowed to stand for two minutes, then made alkaline with caustic soda and filtered immediately. The product consisted of p-nitroso-dimethylaniline, tetramethylbenzidine and a little tarry matter. Since tetramethylbenzidine is sparingly soluble in ether, its separation from p-nitroso-dimethylaniline offers no difficulties. The alkaline filtrate was acidified with hydrochloric acid and any p-nitrosodimethylaniline hydrochloride precipitated was filtered off.

The following table summarises the results obtained:

| Initial Addition of HCl. | From Alkaline Mixture. | | After Acidification. $NO.C_6H_4N(CH_3)_2HCl$. |
|--------------------------------|------------------------|-----------------------------------|--|
| | $NO.C_6H_4N(CH_3)_2$ | $N(CH_3)_2C_6H_4.C_6H_4N(CH_3)_2$ | |
| — | — | 0.015 gram | 0.94 gram |
| 0.1 mol. | 0.025 gram | 0.015 gram | 0.84 gram |
| 0.3 mol. | 0.42 gram | 0.015 gram | Trace |
| 0.6 mol. | 0.91 gram | 0.02 gram | None |
| 1.0 mol. | 0.74 gram | 0.015 gram | None |

When no hydrochloric acid is initially added, therefore, the only reaction proceeding is that of oxidation, no nitrosation having taken place. That the greater part of the nitrous acid and methylaniline has remained unchanged is shown by the large yield of nitroso-compound on subsequent acidification.

Action of Excess of Nitrous Acid on Dimethylaniline.

(a) *Using nitrous acid generated from sodium nitrite and hydrochloric acid.*

Hydrochloric acid (1.21 grams HCl in 10 c.c. water, 2 mols.) was added slowly to a solution of sodium nitrite (2.98 grams, 2.5 mols.) in water (10 c.c.), cooled in a freezing mixture, during twenty minutes. During the addition the temperature remained below 0° C.. Dimethylaniline (2 grams, 1 mol.) was added to the solution of nitrous acid so prepared, with agitation, during ten minutes. The temperature rose slightly, and there was some evolution of nitrous fumes. After five minutes, during which the mixture was occasionally shaken, the precipitated solid was filtered off, pressed and dried in air.

The crude product was washed with cold benzene to remove p-nitrodimethylaniline and 3, 3', dinitro-tetramethylbenzidine, when 2.34 grams, decomposing at 150° C., were obtained. It was crystallised twice from a large volume of methylated spirit, just brought to boiling. The pure product decomposed at 157.5° C.. N found, 21.3%; calculated for $(\text{CH}_3)_2\text{N} \cdot \text{C}_6\text{H}_4\text{NO} \cdot \text{HNO}_2$, 21.3%.

The benzene washings were evaporated, the residue dissolved in methylated spirit and precipitated by the addition of water. The mixture of solids so obtained (0.20 gram) was then dissolved in such an excess of hot methylated spirit that no crystallisation occurred on

cooling. The dinitro-tetramethylbenzidine (about 10% of the mixture) was precipitated on the addition of water, the p-nitrodimethylaniline being recovered by the evaporation of the mother liquor. Each substance was identified by its melting point, alone and mixed with an authentic specimen, and by its nitrogen-content.

Other concentrations of the reacting substances than those used in the above experiments were found to give lower yields of the principal product (decomp. point 157.8°C.).

(b) *Using nitrous acid prepared from "nitrous fumes" and water.*

The fumes obtained by dropping nitric acid of specific gravity 1.35 on to arsenious oxide were passed into water (40 c.c.) until a permanent blue colour was obtained (about thirty minutes). Dimethylaniline (2 grams) was then slowly run into the solution. After standing for two minutes the mixture was treated as described above, 1.08 grams of the principal product (decomp. point 152°C.) being obtained. After recrystallisation the decomposition point was raised to 157.5°C. , and the product was identical with that previously obtained. 3,3', dinitro-tetramethylbenzidine and p-nitrodimethylaniline were also isolated.

Similar results were obtained by passing the nitrous fumes directly into a mixture of dimethylaniline and water, provided the reaction was not unduly prolonged. In an experiment in which the passage of the fumes through dimethylaniline (40 grams) and water (400 c.c.) cooled in a freezing mixture, was continued for seven hours, 13.2 grams of a product were obtained which was identified as the mono-nitrate of tetramethylbenzidine.

p-Nitroso-Dimethylaniline Nitrite and Its Isomerisation.

Finely powdered p-nitroso-dimethylaniline hydrochloride (10 grams, 1 mol.) was added to a solution of sodium nitrite (10 grams, 2.7 mols.) in water (100 c.c.) and stirred mechanically for two hours. The reddish-brown solid was filtered off. On exposure to air, the product became greenish in colour and the odour of nitrous fumes could be detected. The product was allowed to remain on absorbent paper under a clock-glass for two days, after which it was finely powdered and stirred vigorously for one hour with benzene (100 c.c.). The insoluble portion (6.9 grams) had a decomposition point of 153° C., which on recrystallisation from methylated spirit was raised to 157.5° C., the purified material being identical with that obtained in the previous experiments. From the benzene solution 2.6 grams of p-nitroso-dimethylaniline were recovered.

Properties and Reactions of the Substance of Decomposition Point 157.8° C.

Solubility. The substance was soluble in water to a bright yellow solution, but almost insoluble in most organic solvents with the exception of hot methylated spirit which dissolved it to the extent of about 10 grams in a litre.

Behaviour on heating. When heated suddenly it decomposed with a slight explosion. For characterisation of the substance the decomposition point on slow heating was determined.

Decomposition by alkalis. An approximately 5% solution of caustic soda (500 c.c.) was heated to boiling under a reflux condenser to the top of which was attached a tube leading into a dilute solution of hydrochloric acid.

The substance (10 grams) was added in small portions, the mixture being boiled between each addition until the green colour at first developed had disappeared. Dimethylamine was evolved and was recovered as its hydrochloride and identified after evaporation of the dilute hydrochloric acid. The reaction-mixture was boiled for fifteen minutes after all the substance had been added, after which it was cooled in ice, made faintly acid with dilute sulphuric acid and extracted with ether. From the ethereal extract 4 grams of p-nitroso-phenol, melting after recrystallisation at 126° C., were obtained.

Decomposition by glacial acetic acid. The substance (1 gram) was added to boiling glacial acetic acid (20 c.c.), when an immediate vigorous reaction took place with the evolution of nitrous fumes. After cooling to 50° C. the reaction-mixture was poured into water (100 c.c.) with stirring and allowed to stand for twenty minutes. The precipitated solid was filtered off and dried in a vacuum desiccator. After one recrystallisation from methylated spirit, 0.50 gram of p-nitro-dimethylaniline melting at 157.9° C. was obtained, the melting point being raised by further recrystallisation to 160.5° C., unchanged when mixed with an authentic specimen. Further identification was afforded by reduction followed by acetylation when p-acetylaminodimethylaniline, m.pt. 129° C., was obtained.

A further quantity (1 gram) of the finely powdered substance was added to cold glacial acetic acid (40 c.c.) and the temperature slowly raised to $50-55^{\circ}$ C.. After five minutes the commencement of the reaction was indicated by a darkening of the liquid, whereupon the temperature was allowed to fall to $45-50^{\circ}$ C.. After fifteen minutes all the solid had passed into solution, and after another five minutes the reaction-mixture was poured

into water (100 c.c.) and allowed to stand for ten minutes. The precipitated solid was filtered off and dried in vacuo (0.68 gram; m.pt. 75-82° C.). Recrystallisation from methylated spirit raised the melting point to a constant value of 86° C., 0.5 gram of the pure substance being obtained. N found, 21.5%; calculated for $C_6H_3(NO_2)(NO).N(CH_3)_2$, 21.5%. This substance is being further investigated.

Department of Organic Chemistry,
University of Sydney.

THE VOLUMETRIC DETERMINATION OF METHYLENE BLUE AND PICRIC ACID.

By ADOLPH BOLLIGER, Ph.D.

(Read before the Royal Society of New South Wales, Oct. 4, 1933.)

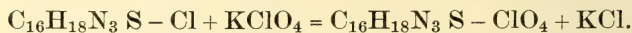
Principle.

The reaction between methylene blue and picric acid has already been used as a qualitative test for the detection of picric acid in urine (Rozier, F., *Bulletin des Sciences Pharmacologiques*, 1917; 24; 81). Methylene blue combines with picric acid to form a well-defined picrate which is only slightly soluble in water but very readily soluble in chloroform.

Reagents.

1. *0.01 N Methylene Blue.*—This is prepared by dissolving 3.74 gm. of methylene blue “Merck”, chemically pure ($C_{16}H_{18}N_3 S - Cl + 3H_2O$) in water, and diluting to a volume of 1 litre.

This solution, after removal of the dye with an excess of perchlorate, can be checked against silver nitrate. About 0.5 gm. of pulverised potassium perchlorate is added to approximately 50 c.cm. After thorough mixing, the precipitated “methylene blue perchlorate” is filtered off. Then, by the usual procedure, the chloride content of a known amount of the solution is determined.



0.01 N and even 0.001 N methylene blue solutions when preserved with a few drops of chloroform and kept in a dark bottle remain sufficiently stable for over a month.

2. *0.01 N Picric Acid*.—2.29 gm. of chemically pure picric acid are dissolved in water and diluted to a volume of 1 litre.

A cold saturated watery solution of picric acid diluted five times is nearly 0.01 N. Such a solution can be standardised against the 0.01 N methylene blue solution by the titration described below.

Titration Procedure.

To determine the methylene blue content of any given solution, the watery dye solution, which must not contain any strong acids or bases, is transferred to a cylindrical separatory funnel containing chloroform. The amount of chloroform to be added depends roughly on the amount of methylene blue present and may vary from about 10 c.cm. to 100 c.cm.

The standard picric acid solution is added from a burette. The methylene blue picrate formed is only slightly soluble in water, but is extracted very readily by the chloroform present in the separatory funnel. The colour of the resultant solution is green. The separation between the methylene blue solution and the chloroform is rapid. If some of the precipitated methylene blue picrate does not immediately dissolve more chloroform has to be added. The colour of the methylene blue solution diminishes to an extent in proportion to the amount of picric acid added, while the methylene blue picrate formed stains the chloroform after its extraction to a correspondingly deeper extent. If the chloroform becomes very dark green in colour, it has to be separated and replaced with fresh chloroform.

The end-point is reached when the watery layer becomes colourless. All the methylene blue present has now been converted into methylene blue picrate which has been extracted by the chloroform. After addition of

an excess of picric acid the watery layer becomes yellowish.

In order to be able to observe the end-point properly it will be necessary when the blue colour of the methylene blue becomes faint to renew the chloroform till it remains colourless after extracting the watery layer. This precaution is necessary on account of the small solubility of methylene blue picrate in water. Also if at an earlier stage there is any doubt about the state of the reaction the chloroform must be renewed.

The end-point is very sharp. One drop of 0.001 N picric acid solution is sufficient to change the solution from distinctly blue to colourless while titrating a 0.001 N methylene blue solution. By using a 0.01 N picric acid solution against a similarly concentrated methylene blue solution it is difficult to observe the colourless stage while the solution changes from blue to yellow.

By this procedure methylene blue in a dilution of 1 in 100,000 can still be determined satisfactorily. When dealing with amounts of methylene blue larger than 1 gm. it is possibly preferable to precipitate the methylene blue picrate with an excess of picric acid without chloroform extraction. The precipitated methylene blue picrate is filtered off and in an aliquot part of the filtrate, the excess of picric acid is determined with standard methylene blue solution (as will be shown in the next paragraph).

To determine the picric acid content, the titration against standardised methylene blue is done by the same technique. The picric acid combines with the methylene blue added from a burette to form methylene blue picrate which in turn is extracted by chloroform. Again the end-point is reached when the watery layer becomes colourless. For practical reasons, it is preferable to

consider as the end-point the first appearance of an unextractable blue colour.

If, in addition to the picric acid, a considerable amount of electrolytes should be present, a small excess of methylene blue may be salted out into the chloroform and the observation of the end-point may be somewhat more difficult. This can be overcome by carrying out near the end-point frequent extractions with small amounts of chloroform. The end-point is reached when one or both of the two layers shows a first appearance of the blue colour of methylene blue.

Three other thiazine dyes besides methylene blue, namely methylene green, thionin (Lauth's violet) and toluidin blue have been tested as regards their ability to form chloroform-soluble picrates. They can all be precipitated with picric acid as chloroform-soluble picrates but their solubility in this solvent is less marked. Methylene green picrate is the most soluble one, while thionin picrate is the least soluble.

Similar addition products to those formed with picric acid (trinitrophenol) are formed with 1:2:4 dinitrophenol by all four thiazine dyes examined. They are also chloroform-soluble. However, the addition product of methylene blue and dinitrophenol is distinctly less soluble than the addition product of picric acid.

SUMMARY.

A rapid and accurate titration method for the determination of small amounts of methylene blue and picric acid, based on the formation of a chloroform-soluble methylene blue picrate, has been described.

The Gordon Craig Urological
Research Laboratory,
University of Sydney.

D—October 4, 1933.

QUANTUM NUMBERS AND VALENCY.

By L. W. O. MARTIN, B.Sc.

(Read before the Royal Society of New South Wales, Oct. 4, 1933.)

Lewis,⁽¹⁾ Langmuir,⁽²⁾ and Sidgwick⁽³⁾ have shown that the concept of the non-ionic bond in chemistry being a pair of electrons is an extraordinarily fruitful theory, and has introduced system into the rather chaotic domain of valency. These authors worked largely from the chemical point of view and were not able to connect the valence electrons very definitely with the physicist's theory of the atom.⁽⁴⁾

Heiliter and London,⁽⁵⁾ on the basis of wave mechanics, produced a very elegant theory of the hydrogen molecule and the chemical inactivity of normal helium. London then generalised the results obtained for hydrogen and considered that the bond consists of a "pairing of two corresponding electrons which belong as unpaired electrons to different atoms."⁽⁶⁾

We will first consider what is meant by corresponding electrons and discuss Pauli's Exclusion Principle. Then we will discuss the hydrogen halides, the carbon halides, the oxygen, sulphur, and nitrogen family hydrides.

The energy or identity of an electron in an atom is specified by a series of numbers which are called its (the electron's) quantum numbers. These numbers in a normal case refer to one nucleus only. They are

n = the principal quantum number which specifies the shell in which the electron is.

l = the azimuthal quantum number.

m = the azimuthal quantum number representing its potential behaviour in a magnetic field.⁽⁷⁾

s = spin of the electron $+\frac{1}{2}$ or $-\frac{1}{2}$.

A corresponding pair of electrons, is a pair of electrons which have n , l , m the same but s opposite, and on the London theory it means that the n , l , are the same with respect to both nuclei.

Pauli's exclusion principle states that only two electrons in any shell of an atom can have n , l , m , the same and s 's opposite. This limits the number of electrons in any shell, since there are relations between n , l , and m . In effect, Pauli's rule makes it possible to say that the maximum number of electrons in a shell n is equal to $2n^2$. Thus the first shell or K level of an atom can have no more than two electrons; the second shell or L level no more than eight, and so on.

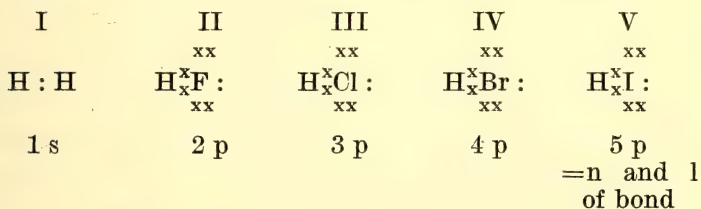
When $l = 0$ we speak of a s electron pair.

When $l = 1$ we speak of a p electron pair.

When $l = 2$ we speak of a d electron pair.

So that a 2 s electron pair means a pair of electrons in the second shell whose $l = 0$, *i.e.*, they are the electrons with lowest energy in the L level.

If we now consider the case of a hydrogen molecule H_2 we can write it as shown below (I), in which the electron pair is shared by both hydrogen nuclei, and thus completes the first shell for each hydrogen atom.



$:=$ a s electron pair
 $\overset{x}{\underset{x}{x}}$ = a p electron pair
 }
 throughout the paper.

This is the normal state for hydrogen, *i.e.*, when the electrons are in the first shell the maximum energy is

required to ionise the molecule. This is to say that when the electrons of an atom are in the normal state (level) they are most strongly bound. When they are in the level next above they are less strongly bound, and so on.

Consider now the molecule of hydrogen fluoride (II), and suppose we are building it up from hydrogen and fluorine atoms. The fluorine atom has a complete first shell consisting of two electrons, with seven electrons in the second shell. Six of these electrons are paired so that there is one unpaired electron. It can be shown that this electron is a 2 p electron. Now the hydrogen atom has one electron in the first shell. It is clear, therefore, that in this case the unpaired electrons are in different shells. How, then, do they pair off to form a corresponding pair? Since the first shell in the fluorine atom is complete, no more electrons can be added to it, so the pairing must take place between a hydrogen 1 s electron and a fluorine 2 p electron. For a corresponding pair of electrons to be formed, the hydrogen electron must be "promoted" to pair off with the fluorine 2 p electron. We thus have as the electron pair, forming the bond between hydrogen and fluorine in hydrogen fluoride, a 2 p pair (II). This is an excited state for the hydrogen, but it must be stabilised by the fluorine. One would perhaps expect that as this is an excited state referred to the hydrogen nucleus, that the energy of dissociation of hydrogen fluoride would be less than that of the hydrogen molecule. This is not the case, and can be readily understood, because of the interactions of the nuclei and the electrons.

A similar treatment of the remainder of the halogen hydrides leads one to the result that the bond between the hydrogen and chlorine (III) is a 3 p one, hydrogen and bromine (IV) a 4 p one, and hydrogen and iodine

(V) a 5 p bond. Thus the electron pair of corresponding electrons in the series becomes more excited with reference to the hydrogen as one goes along; *i.e.*, the bond must become weaker. The results are summarised in Table 1.

TABLE 1.—*Principal quantum numbers and heat of dissociation of hydrogen halides.*

| Hydride. | Bond. | n for normal H. | Heat of Dissociation. ¹ (Q). |
|----------------|-------|--------------------|---|
| | | | Kcals. |
| H ₂ | 1 s | 1 | 103·0 |
| HF | 2 p | 1 | 146·5 |
| HCl | 3 p | 1 | 102·2 |
| HBr | 4 p | 1 | 86·7 |
| HI | 5 p | 1 | 70·9 |

¹Values for Q are from Annual Reports of Chemical Society, Vol. 28, 401 (1931).

It can be seen that the biggest drop in the heat of dissociation is between hydrogen fluoride and chloride. This is parallel to the energies of excitation of the hydrogen atom, as shown in Table 2.

TABLE 2.—*Energy of excitation of hydrogen compared with heat of dissociation of halides.*

| $n_x - n_{x+1}$ | $Q_1 - Q_2$ |
|--|-------------------------|
| $n_2 - n_3$ for hydrogen = 1·88 volts ^s | HF - HCl = 44·3 kcals. |
| $n_3 - n_4$ for hydrogen = 0·66 volts ^s | HCl - HBr = 15·5 kcals. |
| $n_4 - n_5$ for hydrogen = 0·30 volts ^s | HBr - HI = 15·8 kcals. |

where $n_2 - n_3$, *etc.*, is the energy in volts required to excite the hydrogen electron from the second to the third shell, *etc.* We have thus connected the well-known fact that the stability of the halogen hydrides decreases as one goes along the series with the quantum numbers of the elements in the compound.

Similar reasoning, in the case of the carbon-halogen bonds, leads one to predict that the carbon-fluorine bond

will be the strongest, as the principal quantum of the unpaired electrons in the free carbon and fluorine atoms is the same, *i.e.*, there is no promotion in forming the carbon-fluorine bond. Whereas the carbon iodine bond is the weakest, because the difference in the quantum numbers of the unpaired electrons is the greatest, *i.e.*, the promotion of the carbon electron is at a maximum. The results, as known, are shown in Table 3.

TABLE 3.—*Principal quantum numbers and heat of dissociation of methyl halides.*

| Compound. | Bond. | $n_2 - n_1$ | Heat of Dissociation. |
|---------------------|-------|-------------|--------------------------|
| | | | Kcals. |
| H ₃ CF | C—F | 0 | ? |
| H ₃ C Cl | C—Cl | 1 | 73·2 |
| H ₃ C Br | C—Br | 2 | 60·0 |
| H ₃ C I | C—I | 3 | 42·8 |

where $n_2 - n_1$ is the difference between the n 's of the unpaired halogen and carbon electrons.

The data for the oxygen-hydrogen and sulphur-hydrogen bonds are shown in Table 4.

TABLE 4.—*Principal quantum numbers and heats of dissociation of the oxygen and sulphur hydrides.*

| Compound. | Bond. | $n_2 - n_1$. | Heat of Dissociation. |
|------------------|-------|---------------|--------------------------|
| | | | Kcals. |
| H ₂ O | H—O | 1 | 110·0 |
| H ₂ S | H—S | 2 | 87·4 |

In the case of the nitrogen family hydrides, no corresponding data are known to the author, but it is well known that the strength of binding, *i.e.*, the stability of

the ammonia series, decreases as the atomic number of the central atom increases. This is exactly what one would expect on the theory outlined above.

The reactivity of compounds may be briefly considered. As the number of promoted (excited) electrons belonging to any central atom increases, then the strength of the links of the promoted electrons will decrease. The tendency of the electrons to return to their normal state will be increased, as it were. To take a physical example, the energy of excitation of an ionised atom is greater than that in the corresponding un-ionised atom. We predict, then, that as the number of these promoted links increases, then the reactivity or tendency of the central atom to revert to its normal state increases. The only data known to the author on this are the energies of activation of the reaction between sodium and methyl chloride, methylene chloride, chloroform and carbon tetrachloride.

In methyl chloride, one electron of the carbon is promoted, in methylene chloride there are two, in chloroform three, and in carbon tetrachloride there are four promoted electrons. The reactivity then should increase from methyl chloride to a maximum with carbon tetrachloride. Table 5 shows the results obtained by Polanyi.⁽⁹⁾

TABLE 5.—*Number of promoted carbon electrons and energy of activation.*

| Compound. | Number of Promoted Electrons. | Energy of Activation. |
|---------------------------------|-------------------------------|-----------------------|
| CH ₃ Cl | 1 | Cals. 8,800 |
| CH ₂ Cl ₂ | 2 | 4,900 |
| CHCl ₃ | 3 | 2,000 |
| CCl ₄ | 4 | 0 |

The results obtained in the reaction of oxygen atoms with methane and carbon tetrachloride also show the tetrachloride to be more reactive with oxygen than the methane.⁽¹⁰⁾

Numerous examples could be given to show that this simple picture is by no means complete, but it is hoped to discuss these details and further extensions of the theory in later papers.

SUMMARY.

(1) On the basis of London's generalisation of the non-ionic bond and Pauli's exclusion principle, the principal quantum numbers (n , 1) of the electron pair bond between two elements are determined.

(2) The quantum numbers of the electron pair bond are governed entirely by the atom of higher atomic number connected with the bond.

(3) Neglecting other factors, the strength of binding decreases as the difference of atomic number between the elements increases.

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Department of Inorganic Chemistry,
University of Sydney.

THE ORIGIN OF MODERN MOUNTAIN RANGES. WITH SPECIAL REFERENCE TO THE EASTERN AUSTRALIAN HIGHLANDS.

By E. C. ANDREWS.

(Read before the Royal Society of New South Wales, Nov. 1, 1933.)

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ABSTRACT.

Modern mountains may be divided into cordillera and ordinary plateaus. Both types, in reality, are variations of the plateau form, originating in differential vertical movement, or warping (with folding, faulting, and

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lateral gliding) of former low-lying surfaces of erosion or peneplains in varying stages of completeness.

Cordillera occur in the relatively unstable earth zones, while the lower, as also the more typical, plateaus occur in zones of relative stability. Both types are earth undulations, which are crowded together in the cordillera with resultant subparallelism and syntaxis of high ridges and ranges (with appropriate intermontane valleys), but which occur as wide gently undulating uplands in the more typical plateaus.

In the cordilleran areas, the earth's crust has been raised in large geanticlines or earth undulations, which have, or have been, pressed against the more stable portions of the great nuclei of the continental areas, and, by reason of their pronounced elevation above the earth's surface (region of negligible pressure) have sagged in their centres, and have spread outwards by "rock flowage" with the production of lofty upland valleys or plateaus, with bordering ranges arranged *en échelon*, and separated by intermontane valleys, and with outer broken ranges or foothills, this activity being accompanied by local overturning (of anticlines), overthrusting, and extensive crushing of marginal, and practically contemporaneous, outwash.

The lower plateau areas are wide and are characteristic of regions of relative rigidity and strength. Their main points of difference from the typical cordillera appear to be quantitative rather than qualitative.

The main profiles of modern mountains appear to have been formed within the same great division of time, namely, late-to-closing-Tertiary with post-Tertiary.

The formation of the present mountain systems has been a very slow but saltatory process, the long-drawn-

out saltations of undulatory uplift being punctuated by long pauses of relative still stand with widening of valleys by stream erosion.

The earth's crust is in a state approximately of isostatic equilibrium. The tendency to equilibrium, or balancing of crustal irregularities through the medium of a lower "zone of flowage" and compensation is not a predetermining cause, necessarily, of mountain formation, but it does indicate the general form which the approximations to progressive equilibrium will take (allowing for the modifications imposed by local rigidity and strength of the crustal structures), in that it determines the general form and the arrangement of mountains, namely, as earth undulations or waves.

Great cordillera and the main continental plateaus are physiographic unities, and all are dependent on a deep underlying and world-wide control operating in late and post-Tertiary time.

These statements apply to the eastern Australian highlands and the New Zealand mountain systems, which, together with New Guinea, form a compound physiological and geological unity composed of two elements in isostatic equilibrium with each other across the Tasman and associated (related) sea troughs.

INTRODUCTORY NOTES.

When the origin of modern mountains is considered, one notes the extremely important influence of long-continued daily experience and association conjoined to early student training. Thus the alpine geologist envisages the main activity in mountain-making as a movement of lateral compression; the geodesist, from his studies in isostatic equilibrium, sees mountains as products of activities acting in a vertical direction, the

various stages of uplift being always in a state of compensation; the geologist, whose areal surveys have been confined to regions of low-lying plains and plateaus composed of ancient and folded rocks, considers the low plateaus examined by him to be the product of early Palaeozoic compression coupled with continuous erosion subsequently by weathering and stream action, while others see in those same plateaus mere youthful elevations which have only just entered a stage of active stream erosion.

If attention be directed, in this connection, to the highlands of eastern Australia, it will be noted that they belong to the broad plateau or upland valley type of moderate height only. Possibly, by reason of this relative insignificance of the element of height, it has been inferred by some students of land forms that these mountains do not fall within the same category as the present Alpine, Himalayan, or other cordilleran, type. Some students are inclined to consider that there is no physiographic unity in the great province of eastern Australia, but that it is rather the result of differential erosion of a series of heterogeneous and unrelated geological areas; some consider it, on the other hand, as a great geological unity formed by shells of later geological formation successively welded on to ancient nuclei, all of which have been reduced by erosion to the stage of an immature peneplain, and raised in successive steps during the closing, and post, Tertiary periods, by monoclinical foldings, gentle archings, warpings, and faultings. In the latter view, erosive activities are considered as modifying agents only of the main structural profiles. Other students experience difficulty in discriminating between certain sub-summit peneplains

(elevated surfaces of erosion), plateau slopes (structure), and coastal plains or valleys (partly erosion features and partly structural), especially from the points of view of origin and the period of their formation; others experience difficulty in conceiving the general position and attitude of a peneplain surface prior to warping of same; while others again find difficulty in ascribing the share taken by isostatic compensation in the magnitude and form of the plateaus and highlands under consideration.

In view of this divergence of opinion among students, it may be seen that, on the assumption that plateaus, and mountains generally, are the results of well-recognized activities, then it would be of definite assistance—in seeking the explanation of the profiles of highlands in specific areas—to assemble first the information concerning mountain forms and origins generally about which there is a consensus of opinion among the leading observers. Especially valuable, in this connection, would be the collection of the information extant on the extreme forms, because, in such examples, the influence of the main activities in mountain (plateau) formation may be plainly visible, which, though probably equally applicable to the less imposing or spectacular examples, such as those of eastern and Western Australia, may have been obscured, in great measure, by associated activities, which associated activities in turn may have been reduced to a minimum in the extreme mountain type such as that of the Himalaya.

Moreover, in eastern Australia, it has been customary for students of earth forms to confine their physiological observations to one area, summarizing the

main facts of form therein encountered, whether plateau, canyon, plain, continental shelf, ocean deep, and so on, without special reference either to contiguous, near-by, and distant areas, or to the general continental and oceanic setting. On the other hand, it would be helpful to ascertain in what measure the local area selected for special study presents points of similarity or dissimilarity, with its surroundings. Thus one may compare the main features of drainage areas such as those of the Brisbane, Snowy, Murrumbidgee, Shoalhaven, and Hawkesbury Rivers, with the idea of ascertaining any points, of first-rate importance, which may be common to them all.

For the purpose of the present note, the successive steps in the formation of modern mountain systems only are considered. The history of earlier systems, traces of which may be seen abundantly in the folded rocks exposed at the earth's surface, is more complicated, and is reserved for another note in which the general origin of mountains is considered, together with the important part they play in the progressive stabilization of continents. Nevertheless, in order to be reliable and useful, the statements concerning the activities which produced the earlier mountain systems are expected to harmonize, and not to clash, with those which produced the later forms; but attention in this note has been limited to a comparison of present-day forms, structures, and erosive activities, with the object of supplying a simple and satisfactory statement concerning the age and the underlying unity of the activity controlling the formation of the mountains of to-day.

In order to throw light upon this interesting subject, it has been found extremely helpful to study the prin-

cipal mountain systems of the earth in plan as well as in cross-section. For the method of the study in plan we are indebted, in the main, to the work of Suess. Even so, direct observations are confined to the examination of actual rock outcrops, for it is obviously impossible for the student to penetrate the surface of the earth and observe the actual activities characteristic of the deeper portions of the crust. Such surface forms as are revealed at the present surface represent the end results of physical and chemical activities in the abyssal laboratories of the earth's crust, which have been exposed at the surface by subsequent movements of elevation and concomitant erosion.

THE GENERAL FIGURE OF THE EARTH.

The figure of the earth, or the geoid, is taken as the surface of the sea, imagined as coextensive by penetration of the continents in wide canals connecting the various oceans.

This geoid is considered by Helmert and others to deviate only slightly from the flattened ellipsoid of rotation (of the earth's size) with regard to the heights, possibly not exceeding ± 100 metres.

The radius of the earth at the equatorial bulge is approximately thirteen miles longer than the radius, or axis, joining the geoid centre to the poles. So slight, however, is the angular value of the slope of this equatorial bulge that it is not discernible to the unaided eye, and therefore cannot come within the ordinary classification of mountain ranges, nevertheless it reveals the earth as possessing a vast equatorial undulation in equilibrium with relatively low-lying polar areas. In other words, astronomical and geodetic studies have shown the crust to consist of a great earth wave, with

a wide crest in the tropics, flanked by depressions, or rather by relatively-flattened convexities, or depressions, extending throughout the polar areas.

THE OCEAN BASINS AND THE CONTINENTS.

If now attention be directed to the greater divisions of the more superficial portions of the earth, namely, the ocean basins and the continental blocks, it will be noted that the actual area of water is about two and a half times that of dry land, but that this actual area of sea water gives no true idea as to the general profiles of the earth's rock surface.

These oceanic and continental areas may be classified in two ways, namely, latitudinally and meridionally.

1. *Latitudinally*.—Antarctica is a land mass, and its antipodes, the Arctic, is a shallow sea, with a central depression. The "Southern Ocean" belts the earth, and is compensated in the north by Holarctica, or a great land belt in high latitudes. The northern portions of the Pacific and Atlantic are deeper than the southern portions, while the northern portions are associated with large continental areas, the southern lands associated with the oceans being relatively small. The great land blocks, moreover, are hinged along sub-latitudinal zones, passing through the Caribbean area, and along the Tethyan area of Suess, extending from the Pyrenees in Spain to the Malay Archipelago, *via* the Mediterranean, Persia, the Himalaya, and Burmah.

2. *Meridionally*.—The great sub-meridional earth divisions are the Pacific Ocean, North with South America, the Atlantic Ocean, the Atlantic Ridge, Greater Europe with Africa, Asia with Australasia. In this division neither the polar regions nor the Indian Ocean find convenient places.

Whichever way the ocean basins (with the contained oceans) and the continents be considered, they appear to be in a state of approximate isostatic equilibrium or balance with each other. Thus the continents may be considered as complex mountainous or plateau areas separated by great basins with flattish floors. Each continent and ocean basin, in turn, has its rock surface corrugated with ridges and valleys.

Due allowance, in this consideration, must be made for the fact that the earth approximates to an ellipsoid of rotation.

THE PRINCIPAL MOUNTAIN AREAS AND ZONES.

(a) General Peripheral Arrangement to Continents and Continental Nuclei.

In the process of stepping-down, as it were, in the scale of importance, or size, of superficial earth irregularities—from the great equatorial bulge through the ocean basins and the continents—one comes to the main mountain systems proper of the world, as being merely the third order, or series, of earth undulations, or protuberances, with appropriate depressions. These systems, among others, include the North and South American cordillera, with the Labrador, Appalachian and Brazilian plateaus and ranges; the Tethyan mountain zones with their relations and associates; the Scandinavian mountains; the Urals; the Ghats; the mountain rims of the African periphery; the Australasian and Asiatic island arcs; the Australian highlands, and so on.

A feature of great interest to the student of mountains may be noted here, namely, that each continent is bordered by mountain systems, due allowance being made in this statement for various great lowland breaks, or openings, in the mountain borderings, and leading to the

oceans directly. These mountain systems, in their present form and magnitude, approximately, may be considered as of comparable age,¹ mainly closing Tertiary and Pleistocene. This, in itself, suggests a general world-wide control for the activities resulting in the grand mountain systems of the present time.

When, however, these peripheral mountainous areas are considered in more detail, it is noted that they possess a peculiar arrangement and association of related forms. Thus each continental block, with an exception to be mentioned later, possesses cordilleran forms along one side at least, with an opposed plateau system, much inferior in height, along the opposite side at least. The cordillera and lower plateau zones look outward onto the ocean depressions or deep, broad alluviated valleys. The great inland plains themselves usually open out broadly to the sea.

Examples: *North America* is margined on the west by a vast cordilleran belt, which is reflected, or compensated, on the east by the long, relatively-low Appalachian plateau system, the Labrador and the Franklin mountains and plateaus. Between the cordillera and the plateaus lie the prairies and great plains opening to the Arctic Ocean and the Gulf of Mexico, and drained by the Mackenzie and Mississippi stream systems. A minor depression is followed by the St. Lawrence. On each side lies a great oceanic trough.

South America is bordered on the west and north by the Andes and the Venezuelan ranges. On the east lie the Brazilian plateaus and bordering ranges, the two types being separated by the great plains and savannahs drained by the Amazon and La Plata stream systems.

¹ Evidence supplied below.

Each mountain group, whether cordillera or lower Brazilian plateau, looks outwards onto deep ocean, or sea, troughs.

(b) **Broad Topographical Features of the Principal Mountain Systems.**

i. *The Tethyan System from Asia Minor to China.*

This system may be considered as that extensive compound belt of differential uplift which has resulted in the present main topography of Asia Minor, Armenia, Persia, Afghanistan, Baluchistan, the Pamirs, with Thibet and its bordering ranges as far as the Gutters of Kam, or from Lat. 40° N. Long. 27° E. to Lat. 30° N. and Long. 100° E.

This vast and complex geographical feature may be considered as consisting of four or five great plateaus, each bordered by high mountain ranges arranged *en échelon*, and which become approximately confluent at their ends to form imposing mountain knots or multiple ranges separating the various compound plateau types. These plateau areas are Asia Minor, Persia, Afghanistan with the Pamirs and Baluchistan, and Thibet with Tsaidam. Of these, Thibet is the highest and grandest example. This region in common with the other plateau regions mentioned, is traversed by major and minor ranges which wrinkle the surface with *en échelon* undulations, and running parallel or subparallel to the longer axes of the various plateaus. The plateaus are bordered by high mountain ranges, and, in proportion as any particular plateau is emphasised in area and height, so are its bordering ranges increased in number and height, with deep intermontane valleys or upland plains separating them. In the subjoined account, special attention is directed to the Thibetan and associated areas, although

the general topographical description would fit all the Tethyan region through the Pyrenees, the several Alpine areas, Bohemia with the Carpathians, and the area thence to Asia Minor, Persia and Afghanistan (also Burmah and the associated areas).

The Greater-Himalayan-Thibetan Area.

The Himalayas represent the southern wall or face of the plateau of Thibet, while the northern face is buttressed by the Kuen Lun.

If the Thibetan ranges be considered in more detail it may be noted that:

- i. The Kuen Lun forms the northern edge or ridge of Thibet proper.
- ii. The Kara Koram, from its syntaxis with the ranges bordering the Pamirs, passes to the north of the sources of the Indus, and is lost in the Thibetan uplands.
- iii. The Trans-Himalaya traverses the great plateau and forms the northern border of the long valley containing the Brahmapootra and the upper Sutlej.
- iv. The Ladakh Range commences in the same spot as the ranges above-mentioned, and is pierced by the Indus about one hundred miles above Leh. It continues south of the upper Brahmapootra, and merges into the Himalayan system.
- v. The Zaskar, or main chain of the Himalaya, passes from the same great north-western mountain knot mentioned, for a distance of 1,500 miles, in a magnificent curve, with its convexity directed towards Peninsular India. This is the best known range of the Himalaya.

- vi. The Sub-Himalaya, which is "easily defined by the fringing line of hills, more or less broad, and, in places, very distinctly marked off from the main chain by open valleys (dhuns) or narrow valleys parallel to the main axis of the chain".¹ These include the Siwaliks.

The vast Kuen Lun system admits of division somewhat like that of the Himalayas.² The name is used generally to designate "the mountain ranges which run along the northern edge of the Thibetan plateau. In a wider application it means the succession of ranges which extend from the Pamirs on the west . . . until it strikes against, or merges in, the steep escarpments of the south-eastern flank of the Mongolian plateau." As a continuous topographic feature, the Kuen Lun extends as far as the Tsaidam plateau.

The western Kuen Lun and the Astin-Tagh form a great double range bordering western Thibet. The Kuen Lun resolves itself into several mighty undulations (earth wrinkles) forming the continuation east of the northern border of Thibet and overlooking the lower plateau of the Tsaidam (10,000 feet above sea-level). The northern rampart to the Tsaidam is the Astin-Tagh, which becomes multiplied into subparallel ranges and passes into the towering subparallel, and compound, ranges known as the Nan Shan and Richtofen, separated by deep structural (intermontane) valleys. Heights exceeding 22,000 feet occur in all of these bordering ranges of Thibet.

¹ Modified from Sir Thomas Holdich, after Godwin-Austen, in article "Himalaya", *Encycl. Brit.*, Ed. xi. Excellent descriptions of the geography of Thibet and the associated areas are contained in Sven Hedin's works of travel, especially in "Trans-Himalaya", Vol. i and ii, 1906, Vol. iii, 1912.

² Article "Kuen Lun", *Encycl. Brit.*, Ed. xi.

The easterly spread of these Himalayan and Kuen Lun ranges—the mightiest (with the Pamir bordering ranges) in the world—from the Muztah or Pamir knot, is matched by the easterly spread of the high Persian ranges from the famous mountain knot separating Persia from Armenia and Asia Minor.

The Pamirs, the Hindu-Kush, and the Muztagh Ranges.

If the great ranges of the Kuen Lun and the Himalaya be followed westerly, they will be found to osculate in part, and to fuse, in part, near the Pamirs. The Pamirs themselves are a group of structural valleys or plateaus, occupying an area about 150 miles in length and 150 miles in breadth. They are bounded by mountain ramparts, those on the east being parallel towering chains of the Sarikol and Muztagh (highest peak 25,500 feet); on the north by the equally lofty and parallel chains of the Trans-Alai with the Alai; on the south by the stupendous Hindu Kush (highest peaks 24,000 to 25,000 feet) and its formidable parallel ranges in the Gilgit-Kabul sector; and on the west by the great and wild double ranges forming the eastern boundary of Badakshan.

The average height of the main or true Pamirs, in their upper portions, is 13,000 feet approximately, as compared with Thibet (15,000 to 16,000 feet) and the Tsaidam (10,000 to 11,000 feet), while the lofty ranges bounding them rise in places to heights of 25,000 feet on the eastern, northern, and southern sides at least. The wild and glacier-laden Nicolas Range separates the northern and southern main Pamirs, while the eastern Pamirs are high structural valleys lying between the parallel ranges of the Sarikol and the Muztagh.

It will be seen thus that the Pamirs represent a grand meeting-place for the massive east and west ranges of Tethys as they bend round the resistant massif of Peninsular India. Thus the Astin Tagh and Arka Tagh fuse, or enter into syntaxis, westerly, and appear to pass gradually into the meridional Muztagh at the Raskem River. The Kara-koram and the Trans-Himalaya pass into the meridional wall of the Sarikol, which runs parallel with the Muztagh. The Ladakh and main Himalaya also trend towards the Pamirs, forming a compound and parallel undulation to the south of the Great Pamir. The Sarikol and the Muztagh ranges appear to be welded to each other to the south, and their western course by Afghanistan is taken by the Hindu Kush, which forms a great double southern chain or border to the high plateau of North Afghanistan and Badakshan. North of the Pamirs the Sarikol changes its course to the west and passes into the lofty Trans-Alai, which, with the parallel Alai, forms the great double northern wall of the Pamirs. Associated with these compound natural ramparts lie the vast low-lying areas of East Turkestan, and within them also lies that portion of West Turkestan drained by the upper Oxus.

The topography of Afghanistan, Persia, and of Asia Minor, is similar, in a general way, to that of the areas above described, with the modification that, in proportion as the area and height of the central plateaus of these regions are diminished, so also are the attendant earth undulations (mountain ranges) diminished both in number and in height.

ii. *The Andes and the Brazilian Plateaus.*

The authorities relied on mainly for a summary statement of the Andean topography are the authors of the

various articles on Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador and Peru in the eleventh edition of the *Encyclopædia Britannica*, together with Berry and Singewald,¹ Bowman² and Gregory.³

The Andes, the second in order of the great mountain systems, forms a continuous chain of highlands along the western side of South America. A comparison with the Brazilian plateaus is supplied later, as in the case of the comparison of the Tethyan system in the Thibetan sector with the Ghats of Peninsular India.

The Andes are, approximately, 5000 miles in length, and taken in a broad sense, they consist of high plateaus bordered by lofty compound, but subparallel or sympathetically-curving ranges, which, throughout the greater part of their course, are accompanied by deep longitudinal valleys both east and west of the main Andes; farther west lies a series of ocean trenches subparallel to the main Andean trend; while to the east the main mountain massif is accompanied by subparallel "sierras" or foothills, abutting on, or margining, the great inland plains. The plateaus, or upland valleys, appropriately attain their maximum height and width opposite to the main mass of Brazil. The Andean system here varies from 100 to 500 miles in width. These plateaus, in their finest development, extend from Columbia in the north to the southern end of the Puna de Atacama in the south, a distance exceeding 2,000 miles. As shown below,

¹ Berry, E. W., and Singewald, J. E.: "The Tectonic History of Western South America", *Proc. Third Pac. Sci. Congress* (Tokyo), 1926, pp. 431-439.

² Bowman, Isaiah: "The Andes of Southern Peru", *Am. Geog. Soc.* Holt & Co., 1916.

³ Gregory, H. E.: "A Geologic Reconnaissance of the Cuzco Valley, Peru", *American Journal of Science*, Vol. 41, 1916, pp. 1-100.

these upland expanses are not only bounded or bordered by lofty compound ranges, but are also traversed longitudinally, in great measure, by subparallel ranges; moreover, they are tied across by transverse ranges and ridges known as paramos and mountain knots. Some of these mountain knots are famous and form natural north and south boundaries between countries such as Columbia, Ecuador, Peru, Bolivia, and Argentina. Farther from the apparent influence of the Brazilian massif, the Andes contract into a series of lofty parallel ranges, separated by relatively low-lying narrow valleys.

In this general statement may be seen the striking similarity of plan exhibited in the topography of the Andean and Tethyan regions. As with the Tethyan mountain system and its immense latitudinal extension respectively south-easterly from Thibet and westerly from Asia Minor, so also the Andean system branches to the north and north-east as the Venezuelan cordilleran system, the Maracaibo system, and the Central American cordillera, while southwards it passes in a great compound curve to Antarctica by way of the Falklands, South Georgia, the Sandwich Islands, and Graham Land.

In its simplest form the Andean system consists of two principal chains, with an intermediate depression, in which, and at the sides of the stupendous chains themselves, "are arranged other chains of minor importance, the chief of which is that called the Cordillera de la Costa (Coast) of Chile. This starts from the southern extremity of the continent, and runs in a northerly direction, parallel with the coast, being broken up at its beginning into a number of islands, but forming, farther to the north, the western boundary of the great central valley of Chile. To the north, this coastal chain

continues in small ridges, or isolated hills, along the Pacific as far as Columbia, always leaving the same valley more or less visible to the west of the western great chain.”¹

This arrangement is significant in connection with the question of volcanic action, considered in a later section. The Cordillera de la Costa, which begins near Cape Horn, attains heights which are inconsiderable as compared with those of the main central ranges.

So also, on the eastern side of the southern Andes, and corresponding to the great low depression separating the Costa from the main Andes, there is a longitudinal depression “separating the Andes from some independent ridges pertaining to a secondary parallel broken chain called the pre-Cordillera.”

To the north of 45° Lat. S., a well-defined longitudinal valley, which divides the main Andes into two chains, has the eastern chain as its main boundary; the western chain, however, contains several high volcanic peaks.

About Lat. 38° S., the Andes assume a great transverse extension, but, whereas the main ridge, or crest, is well defined, there are no wide intermediate valleys between the various longitudinal ridges. Still farther north, the Cordillera open out again into two huge main ranges, which reunite about the latitude of Valparaiso.

In Argentina the high plateau is called the Puna de Atacama, and is from 11,000 to 13,000 feet in height, being bounded on the west by the Cordillera Occidental (Cordillera de los Andes), and on the east by the Cordillera Oriental. To the north it is bordered by the ranges at the Bolivian boundary, where the Sierra de Lipaz forms a transverse knot joining the two great

¹ “Andes”, *Encycl. Brit.*, Ed. xi.

ranges. The massif of the Bolivian highlands sends out several ranges to the south, and these are separated from the main chain by structural valleys, they themselves forming the eastern ramp of the vast central plateau, of which the Puna de Atacama occupies the main portion. These eastern ranges are subparallel, and are arranged *en échelon* with the Andes proper, and they die out in the high western pampas. They are flanking ranges, or foothills, to the lofty cordillera and plateaus, and are the eastern homologues of the Cordillera de la Costa lying to the west of the main chain.

North of this area, in Bolivia, occurs the most magnificent development of the Andean system. Here it is composed of a number of parallel ranges, enclosing vast elevated plateaus, whose coextension is interrupted by transverse ranges. Lake Titicaca (12,760 feet above sea level) and its associates occur here under the Nudo (knot) de Aplobamba, lying to the north-east. From, and below, this Nudo the ranges open out and enclose extensive plateau areas.

This great tableland development in Bolivia is five hundred miles in length, and eighty miles in breadth, involving an area, approximately, of forty thousand square miles. In the north it is known as the Puna; in the south as the desert of Lipaz, being a natural extension north of the Puna de Atacama. This so-called *altiplanicie*, or high plain, is bounded on the north by the massive Vilcanota knot separating Bolivia from southern Peru; on the west by the Cordillera Occidental; on the east the Cordillera Oriental forms its mighty rampart. This mountain system extends northward into Peru as the Carabaya, fusing in turn with the mighty central Cordillera Real in the Vilcanota knot. To the south the

eastern rampart takes the form of broken subparallel ranges, the whole southern area between the Cordillera Real and Cochobamba consisting of ranges arranged in sympathetic curves. The eastern rampart itself consists of two distinct chains, the Sierra de Cochobamba and the Sierra de Misiones. The Cordillera Real is a very important third or central range extending throughout Bolivia between the main east and west cordillera. The eastern rampart again is flanked by relatively low, wooded, subparallel but broken ranges arranged *en échelon*.

Passing northwards into Peru, the sierran belt is two hundred and fifty miles in width. As in Bolivia the high plateaus or plains, exceeding 10,000 to 12,000 feet in height, extend throughout the whole length of Peru, a distance of many hundreds of miles. Transverse ranges border the high puna or plains at the Bolivian border to the south and the Ecuadorian border to the north.

Three distinct chains, the western, central and eastern, cordillera, form the borders of the high plateaus, or upland valleys, and these ranges are continuations northwards of the cordillera of Bolivia and Argentina. The two cordillera of the western side are parallel to each other and are separated, in turn, by puna dotted with lakes. The Central Cordillera is tied to the main compound range at the Vilcanota knot, and again in Lat. 10° S. near Cerro Pasco.

"South of the Loja knot in Peru, the western Andes or Maritime Cordillera extends southward west of Marañon as the lofty snow-clad Cordillera Blanca, and lying west and parallel with it is the Cordillera Negra, the two separated by the Huaylas valley. . . . So far as I know, Bowman is the only one of the many describers of Andean landscapes that has a clear and correct understanding of them. Most observers speak of the massive proportions and disorderly arrangement. Nothing is farther from the facts. In this part of their extent the system consists, in reality, of three great parallel plateaus or table-

lands, the central lying from 1,000 to 2,000 metres below the Eastern and the Western, the former modified by the residual peaks and ranges which it bears and the latter similarly modified by volcanic cones."¹

Ecuador.—Immediately beyond the transverse range forming the northern border of Peru, the great plateau belt reappears in Ecuador, and in line with the southern examples. It traverses the whole length of Ecuador, being three hundred miles in length and from twenty to thirty miles in width. It ends again at the knotting of the ranges at the Columbian boundary. This Ecuadorian upland system falls naturally into four large parks or plateaus, separated by transverse ranges (the Tuipullo Azuay paramos), and on the south, between Ecuador and Peru, by the Loja Knot. These high level plains are lower than the altaplanicie of Peru, Bolivia, and Argentina. Thus the Quito plateau is 9,500 feet, the Ambato 8,500 feet, Cuenca 7,800 feet, and the Loja Basin somewhat lower again. The "parks" lie between two great ranges, known as the Cordillera Occidental and the Cordillera Oriental, which run practically parallel to the 77th and 79th meridians. Both ranges are lined with majestic volcanoes. The western cordillera is parallel to the coast, from which it is separated by a low coastal range with an intermediate valley.

Columbia.—Towards the Ecuadorian frontier the main Columbian ranges have diverged from the Imbabura knot. These Columbian Andes are divisible into three main chains, and they are continuations of the Andean chains of Ecuador. The western chain is regular, and contains peaks rising between 11,000 and 12,000 feet. The central chain, separated from the western and eastern chains

¹ Berry, E. W., and Singewald, J. T.: "The Tectonic History of Western South America", *Proc. Third Pac. Sci. Cong.* (Tokyo), 1926, Vol. i, pp. 433-434.

respectively, by the valleys of the Cauca and the Magdalena, supports volcanoes, and reaches an extreme height of 16,000 feet, approximately. The eastern chain commences at a height of 6,000 feet, but attains an extreme height of 16,700 feet farther north, in the Sierra Nevada de Cochi.

The great Brazilian plateau, which is the most important division of Brazil, consists of an extensive tableland, rising from 1,000 to 3,000 feet above sea-level, traversed by two great mountain systems.¹

The erosion of the sandstone capping to the plateau gives the appearance, from certain vantage points, of ranges of mountains, but they are only erosional scarps rising to plateau levels. The only "mountain systems" as the term is usually understood, are the two parallel compound ranges which follow the Brazilian coast, and those which comprise the central, or Goyana, system.

The first of these two systems is at least double, consisting of:

- i. An easterly member persisting almost continuously from the south of Brazil to a point near Cape Frio, thence in broken ranges to Cape St. Rogue, approximately, or the great western turn of the continent.
- ii. A second parallel range following the more easterly belt, on the inland side, for very great distances.

The coastal range has many names, with its culminating point (7,323 feet) near Rio de Janeiro. The inland range has various local names, and its height exceeds that of the coastal group, the culminating point being Itatiaya, estimated at 9,000 feet approximately. This inner range is described as forming "the true backbone of the maritime mountainous belt, and rises from the

¹ "Brazil", *Encycl. Brit.*, Ed. xi.

plateau itself, while the Coast Range rises on its eastern margin and forms a rim to the plateau."¹

The Central System consists of two distinct chains converging to the north in an elevated plateau. The culminating points in the two systems (east and west) are 4,206 feet and 4,500 feet respectively, above sea level.

Plateaus, or broad upland valleys, occupy the space between the compound coastal system.

iii. *The North American Cordillera and the Appalachian System.*

The North American Cordillera.—The accompanying notes are based partly upon personal observations and partly upon a study of the writings of Brock,² Brooks,³ Fenneman⁴ and Lake.⁵

A broad general review of that vast area known as the North American Cordilleran region, in its most extended sense, suggests a striking likeness, topographically, to the Tethyan and Andean areas, namely, that it consists of a great series of high plateaus following a general curve; bordered by lofty compound ranges, and interrupted in longitudinal continuity by transverse ranges or mountain knots, so as to group them into large natural divisions. These plateaus and bordering ranges again descend to, or are accompanied along, the inland plains, by lower curving foothills, arranged *en échelon*. The main chains also are separated from the ocean proper by high coastal

¹ *Encycl. Brit.*, *ibid*.

² Brock, R. W.: "Structure of the Pacific Region of Canada", *Proc. Second Pan-Pac. Sci. Cong.* (Australia), 1923, Vol. i, pp. 776-783.

³ Brooks, A. H.: Geographical Notes in article "Alaska", *Encycl. Brit.*, Ed. xi.

⁴ Fenneman, N. M.: "Physiography of Western United States", McGraw Hill, 1931.

⁵ Lake, Philip: "Mexico", *Encycl. Brit.*, Ed. xi.

ranges, and deep intermontane valleys paralleling the main cordilleran trend. In the northern portion of the continent the outlying subparallel ranges occur as great island arcs associated with deep seaways or fiords.

One feature which causes an apparent divergence of design between the North American cordillera and the more simple plan of the Tethyan and Andean groups is the occurrence, within the North American cordillera, of an ancient (early Pre-Cambrian) inlier of subcontinental size, and around which the main ranges have been moulded, giving the region an abnormal width in the Colorado, Arizona, New Mexico, Utah-Wyoming areas. The significance of these ancient inliers in continental growth and stabilization is considered in a later part of this series of papers.

Examples.—The United States: The western portion of the United States is a northern continuation of the geographical unity of Mexico. In the description of its topography, it will be found profitable to adopt the valuable tabular summary of Fenneman,¹ for this area, which is about 1,400 miles in length.²

Fenneman's major divisions comprise:

- (a) The Rocky Mountain System.
- (b) The Intermontane System.
- (c) The Pacific Mountain System.

In Fenneman's more detailed subdivision, the Rocky Mountain, or inland, system, is divided (on a northerly traverse) into the Southern Rocky Mountains; the

¹ Fenneman, N. M.: "Physiography of Western United States", Ginn & Co., 1928.

² Another valuable summary of this region, especially from the point of view of genesis, is by A. C. Lawson, "The Cordilleran Shield", *Proc. Third Pac. Sci. Cong.* (Tokyo), 1926, Vol. i, pp. 371-388.

Wyoming Basin; the Middle Rocky Mountains; and the Northern Rocky Mountains. Of these, the southern group consists of high compound ranges of various types with intermontane basins or valleys; and the Wyoming Basin, consisting of elevated plains in various stages of erosion, bordered by high compound ranges and diversified with isolated mountains, of relatively low vertical relief. The Middle Rockies consist of compound ranges mainly of the anticlinal type and enclosing intermontane basins. The Northern Rockies comprise dissected compound mountainous uplands, apparently not of anticlinal type. These enclose intermont basins.

The irregular longitudinal zone adjoining the Rockies on the west is the area of Intermontane Plateaus, comprising:

- (a) The Basin and Range Province.
- (b) The Colorado Plateaus.
- (c) The Columbia Plateaus.

Example: The Basin and Range Province.—Broadly, it may be said of this area that it is a plateau of variable height, bordered east and west by high compound ranges and plateaus opening out widely in the middle portion and tending to be cut off by the approach of mountains to each other to the south, and containing very many high ranges arranged longitudinally and *en échelon*, as though under one great topographical control.

The Third, or Pacific Mountain System, is divided into three portions:

- (a) The Lower Californian Province.
- (b) The Sierra-Cascade Province.
- (c) The Pacific Border Province.

The Lower Californian Province consists, in its northern portion, of a dissected granite upland with westward slope.

The Sierra-Cascade Mountains lie between the Intermontane Plateaus and the Pacific Ranges. They are subdivided into four sub-provinces, arranged approximately meridionally; the Sierra Nevada, a block mountain range tilted to the west, with accordant crests and with a group of Alpine peaks near its eastern margin; the Southern Cascade Mountains, a zone of volcanic mountains differentially eroded; the Middle Cascades, a mountain zone rising generally to accordant summits, with higher volcanic cones; and the Northern Cascades, sharp alpine summits rising to accordant heights and surmounted by higher volcanic cones.

According to Fenneman, the Pacific Border Province, traced from south to north, comprises seven natural divisions, namely, the Los Angeles section, consisting of narrow ranges and dissected fault blocks with alluviated lowlands; the Californian Coast Ranges, a series of "parallel ranges and valleys, on folded faulted rocks," with rounded crests of subequal height; the Californian Trough, consisting of low fluviatile plains; the Klamath Mountains, an "uplifted and dissected peneplain on strong rocks, with extensive monadnocks"; the Oregon Coast Range, an "uplifted peneplain on weak rocks", dissected with monadnocks of igneous rocks; the Olympia Mountains, a compound mountain zone with crests, generally accordant, and with local Alpine peaks; the Puget Trough, a series of lowlands of diverse character, and in part submerged.

This western division of the United States might have been described as a double series of parallel to sub-parallel compound ranges, separated by structural intermontane valleys and troughs, the latter, in turn, being separated by the syntaxis, osculation, fusion, or knotting,

of the great subparallel mountain systems. Thus, the Sierra Nevada and the Cascades form the grand eastern mountain zone of compound nature, and the Pacific Coast Ranges the western group, these being separated by the intermontane troughs and valleys known as Puget Sound, the Willamette Valley, the Great Californian Valley, and the more constricted valleys to the south. These longitudinal intermontane valleys are interrupted and separated by the transverse Klamath, Siskyou, Tehachapi and other mountain masses.

The Canadian Cordilleran Section.

The large region of this name is a natural northern extension of the cordilleran area of the United States, and admits of the same division into longitudinal plateaus bordered by compound ranges, separated from the Pacific by high parallel, subparallel, or sympathetically-curving mountain lines. These mountain belts or lines are compound, and are separated from each other by seaways and intermontane valleys.

Brock,¹ describing this area, states that:

"It is mountainous throughout, for, while broad plateaus occur between some of the present dominant ranges, they are, in reality, mountain torsos, and, due to late-geological elevation, are dissected by valleys thousands of feet deep, so that, as a rule, it is only from elevations that the plateaus can be recognized."

Brock points out, moreover, that the "Plateau" region to the northward may be subdivided naturally into several areas. Thus, in southern British Columbia, the plateau area appears to be a warped peneplain of well-marked character, and sloping northwards from an approximate elevation of 5,000 feet at the United States boundary to 3,000 feet in central British Columbia. To the north, the Yukon Plateau has an elevation approxi-

¹ *Op. cit.*, p. 777.

ating to 5,000 feet. These plateaus are deeply dissected, in places, the stream channels being less than 1,000 feet above sea-level. The Plateau region and the Cascade Range are not sharply distinguished, as they merge the one into the other, "but the Coast Range rises sharply from the Plateau at least as far north as Lat. 54° N."

These elements fall naturally into three belts: "a western belt of Alpine mountains; an eastern belt of Alpine mountains, and between these, a central belt of plateaus with some mountains."

These major divisions, including the Yukon Territory, are about 1,300 miles in length, and, in common with the similar threefold division of forms in the neighbouring United States, and Alaska, they admit of more detailed natural subdivisions. Thus:

"The western belt is subdivided into the Vancouver system of the island fringe, Vancouver, Queen Charlotte, and the Alaskan Islands; and the Pacific System, that is, the Coast Range, and, east of the Fraser River, and south of the Thompson, the Cascade Range.

"The Central Plateau belt is sometimes . . . sharply separated from the Pacific system. In the east it gradually rises into the Eastern belt. The plateau surface, in places, is broken by monadnocks, or ranges of granitoid rocks.

"The Eastern belt is subdivided into the Gold Ranges, with the Rocky Mountain (the former embracing the Columbia Mountains), and the Selkirk system, consisting of the Selkirks proper and the Purcell Mountains.

"The Columbia Trench, an erosional valley, occupied by the northward-flowing Kootenay River, Kootenay Lake, the Duncan and Beaver Rivers, separates the Selkirks and Purcells. The Rocky Mountain Trench, a great structural valley occupied by the Kootenay, Columbia, and many other rivers, separates the Purcells and Selkirks from the Rocky Mountains."¹

The Canadian central plateau system may be considered as being separated from the interior plateau system of the United States (at the Columbia Plateau, and so on), by the development of mountain chains (the Purcells, Selkirks, the Flathead, Cabinet, Cœur d'Alene,

¹ Brock: *Op. cit.*, p. 778.

Pend d'oreille, Rossland, and Okanagan Ranges, the Cascades, and other ranges) to form the equivalent of a great mountain knot at this locality.

The Yukon Section of Canada is not considered in this brief summary of topographic forms, beyond stating that it is a natural extension of the geographical provinces described as above by Brock.

These mountain belts, in common with those of the Alpine, or Tethyan, areas of Europe and Asia; of the Andes; of the cordillera of Central America and of North America, generally, are described in these notes as not only compound but as consisting of parallel to sub-parallel ranges, separated by structural intermontane valleys.

It is advisable to remember, however, that although this statement is one which is convenient for general description, nevertheless the ranges under consideration may be observed to widen and contract repeatedly; they appear to join by osculation, syntaxis, or by the development of transverse ranges and mountain knots; their summits do not rise to a uniform level, but on the contrary they possess plunging crests. A great compound wall, as seen from a neighbouring plain or wide valley, may be interrupted, or crossed, by a series of structural gaps, determined by crest undulations, and these low gaps or breaches may be expected to be arranged in a sort of side-stepping manner. Thus the description of the cordillera as consisting of sub-parallel to parallel ranges, rising to accordant heights, is to be understood only in a general way. The main fact to be borne in mind, in this connection, is the general sympathy of curvature of mountain ranges and associated continental coast or deep alluviated plain (trough) so as to suggest an underlying unity of structural control for any specific

cordilleran system, such system being related intimately, on the one hand, to the containing continental element and its margin, and, on the other hand, to the neighbouring ocean and inland plains.

The Appalachian Highlands.—The following notes have been taken from the published accounts of Davis,¹ Fenneman,² and Spencer.³

The name "Appalachian Mountains" is a general one "given to a vast system of elevations in North America, partly in Canada, but mainly in the United States, extending as a zone, from 100 to 300 miles wide, from Newfoundland, Gaspé Peninsula, and New Brunswick, 1,500 miles south-westward to central Alabama. The whole system may be divided into three great sections; the *Northern*, from Newfoundland to the Hudson River, the *Central*, from the Hudson Valley to that of New River . . . in Virginia and West Virginia; and the *Southern*, from New River onwards."

A striking feature of the area is the Great Appalachian Valley in a longitudinal chain of broad valleys which, in its southern portion, separates the mountain system "into two subequal portions", whereas, in the far north, it lies to the west of all the ranges possessing typical Appalachian features. Nevertheless, in spite of the existence of this great longitudinal valley feature, the main streams of the Appalachian system are transverse to the longer axis of the system. Davis states that the valley form has resulted from the existence there of weak limestone, shale, and (or) slate, adjacent to the crystalline uplands on the east. He points out also that

¹ Davis, W. M.: Article, "United States", *Encycl. Brit.*, Ed. xi.

² Fenneman, N. M.: "Physiographic Divisions of the United States", *Am. Ass. Am. Geographers*, pp. 281-307.

³ Spencer, A. C.: "Appalachian Mountains", *Encycl. Brit.*, Ed. xi.

“the boundary between the mountains and the piedmont belt is called the Blue Ridge all along its length, and, although the name is fairly appropriate in northern Virginia, it is not deserved in the Carolines, where the ‘Ridge’ is only an escarpment descending abruptly 1,000 or 1,500 feet from the valleys of the mountain belt to the rolling uplands of the Piedmont Belt.”

The highest points in the Appalachian System occur in the south, where the Unaka Ranges possess peaks from 5,000 to 6,000 feet in height, the Smoky Mountains, 5,000 to 6,636 feet, and the Black Mountains, with Mt. Mitchell, 6,711 feet, as the culminating peak in the whole system.

iv. *The Australasian Island Arcs and the
East Australian Highlands.*

The areas selected for brief description in this division are Eastern Australia, New Zealand, and New Guinea.

In this group the long compound island arc of Suess—extending from New Guinea to New Zealand, by way of New Britain, New Ireland, the Solomons, and New Caledonia—is considered as the homologue of the cordilleran areas described above; the Arafura, Coral, and Tasman basins, as the forms corresponding to the great plains of the main continents; while the Eastern Australian highlands are the equivalents of the Indian Ghats, the Scandinavian Mountains, the Ural Mountains, the Brazilian ranges and plateaus, the Appalachian system, and so on (the Western Australian plateaus and the Great Inland Plains of Australia are reverberations, in part, of the activities in the east, and, in part, a compromise between the Pacific and Indian Ocean activities).

The Cordilleran Area (Insular Arcs).

(a) *New Zealand*: The topography of New Zealand was described by Marshall¹ many years ago, and the topographic information supplied here has been gathered from a study of his maps and descriptions.

W. N. Benson and C. A. Cotton have made very important contributions to our knowledge of the origin of the topographic forms, and to their more recent work, as well as to the earlier work of Marshall, the notes concerning New Zealand in a later chapter of this report are much indebted.

The North Island possesses a series of sympathetically curving mountain ranges passing along its eastern side. The main belt is composed, from a point near Wellington in the south to East Cape in the north, of the Rimutaka, Torarua, Ruahine, Hinarau, and Roukumara Mountains, ranging from 3,000 to 6,000 feet in height. These are deeply indented with structural gaps, and are arranged, in somewhat offsetting manner, at a few places. To the east, and parallel with them, are the broken ranges known as the Haurangi, Puketoi, and other groups, whose elevations, however, do not exceed 3,000 feet. Both to the east and west of the central forms of the main axis other shorter subparallel, and *en échelon*, groups, occur—rising to 6,000 feet on the west—and forming a kind of incomplete knot. Westward of these ranges, in turn, occurs the important, and compound, zone of volcanic peaks and plateaus. The main belts, lying eastward of the volcanic zone, are separated from each other by structural valleys. Ranges and valleys alike have been much modified by erosion.

¹ Marshall, P.: "Geography of New Zealand", Whitcombe and Tombs.

The ranges of the long north-western arm of the island are of inconsiderable height, but their main trend is characteristically marginal.

The South Island possesses a long main axis, known as the Southern Alps, consisting of a main ridge, in the south-west, rising from a raised and dissected peneplain and trending sympathetically with the associated coast zone to the neighbourhood of Milford Sound and Martin's Bay, from the latter of which its crest rises, in undulating nature, to the neighbourhood of Mount Cook (12,359 feet); and thence falling, with undulating pitch towards Pelorus Sound *via* the Spencer Mountains (7,500 feet), St. Arnaud Mountains (5,000 feet), and other ranges somewhat less in altitude.

Subparallel with this compound belt, in the north-eastern portion of the island, lie the Seaward Kaikoura (8,000 feet), the main Kaikoura (9,000 feet), and other high, but lesser, ranges. These all appear to be separated by structural valleys. Farther south, but still on the eastern side of this portion of the island, occur the short, broken, and aligned, ranges of Mount Somers (5,500 feet), Mount Hutt (7,000 feet), Mount Torlesse (6,500 feet) and Paketeraki (5,500 feet) ranges. To the west of the Alpine backbone, and in the north-western portion of the island, between Hokitika, on the south, and the Golden Bay area, to the north, other ranges occur with trends subparallel to parallel with the general strike of the Southern Alps, namely, the Paparoa Mountains (4,000 feet), the Lyell Mountains (5,000 feet), the Pakikiruna Mountains and the Brunner Ranges (5,000 feet). These are separated from the main range, and from each other, by an extensive longitudinal and relatively-depressed area, interrupted here and there in its topographic uniformity by the development therein of transverse

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ranges. This depression appears to pass southwards along the coastal region to the Haast River, where it is intercepted by a mountain knot near the heads of Lakes Wanaka, Wakatipu, Te Anau, and the Cascade Point-Milford Sound area. Beyond this, to the south, Marshall's maps and models indicate its continuance as a weaker fact of form through the fiord region.

(b) *New Guinea*.—The authorities followed here are David,¹ the Stanleys,^{2 3} and Zwierzycki.⁴

New Guinea is an island with an area, approximately, of 306,000 square miles, and a length of 1,500 miles. The topography consists, in the main, of lofty compound longitudinal ranges, separated by persistent structural valleys, and bordered on the south by a series of extensive lowlands.

The main range forms the backbone of the island, comprising the Sneeuw Mountains, in Dutch New Guinea, the Charles Louis Range, the Victor Emmanuel, and Bismarck, Ranges, and the Owen Stanley Range. These are all characterized by great elevations, several peaks in Dutch New Guinea rising between 15,500 and 16,000 feet, while others in Papua, and the Mandated Territory, attain heights of 13,000 feet.

Lofty ranges also margin the northern coastal area, attaining heights of 12,000 to 13,000 feet. They are interrupted by wide low gaps. Several unimportant breaks occur also in the main central axis of the island.

¹ David, Sir T. W. Edgeworth: "Geology of Papua", Federal Handbook Brit. Ass. Adv. Science (Australia), 1914, pp. 316-325.

² Stanley, Evan R.: "Topographical Features of New Guinea", *Proc. Pan-Pacific Sci. Congress* (Australia), 1923, Vol. i, pp. 683-686.

³ Stanley, G. A. V.: Personal communication.

⁴ Zwierzycki, J.: "Tectonic Movements in the East Indian Archipelago", *Fourth Pacific Science Congress* (Java), 1929, Vol. i, pp. 279-281, with excellent map.

In addition to these subparallel northern and southern (central) cordillera, there are various parallel ranges, "virgations", and knots. According to Evan Stanley, two or more ranges rise to accordant heights, suggesting the existence of a dissected plateau varying in height from 5,000 to 6,000 feet.

Again, according to the same authority:

"It is remarkable that the highland country of New Guinea should cover such a large area, the many peaks and ridges, with few exceptions, in the 'Main Range' zone being somewhere in the same level, suggesting the idea of a peneplain in an altitude of 11,000 to 13,000 feet."

Some of the most prominent features in the New Guinea topography are the long intermontane valleys trending parallel with the general strike of the main compound ranges both north and south. Thus between the main mountain axis and the northern ranges, the island is traversed from the MacCluer Gulf to the Huon Gulf by a vast depression, interrupted only, in the main, by low transverse divides. This great compound valley comprises the main courses of the Mamberano, Sepik, Ramu, and Markham Rivers. To the south a similar feature is drained by portions of the Fly, Strickland, Purari, Digoel, and other, streams. Zwierzycki also stresses the significance of the "longitudinal depression which we may trace along the southern border of the Central (Main) Range. Here enormous swamps extend, and deep, canal-like inland connections exist between the river systems". Virgation, syntaxis and knotting are indicated also by a study of the associated d'Entrecasteaux, Louisiade, Admiralty, New Britain, New Ireland, and Solomon, island groups.

(c) *The Eastern Australian Highlands*.—The general profiles of the Australian topography exemplify the empiric law that continents possess high borders (with large interruptions) and depressed interiors.

At first glance, the student untrained in physiography might be inclined to consider the Eastern Australian highlands as a mere chaotic jumble of plateau escarpments, isolated peaks, with cross ridges tying shoreline to plateaus, and with tablelands canyoned deeply on their eastern and western slopes. The term "Main Dividing Range", to such an observer, would seem to be a mere euphemism, inasmuch as the actual water parting, in many areas, is situated on the upland plains, and is only distinguished from the general undulating surface with difficulty in such cases. Here and there, moreover, the plateaus are interrupted by extensive low breaks or gaps, and, in addition, the various uplands do not dip normally from a central axis towards the coastal and inland plains, after the fashion of an ordinary hip roof, but slope indifferently, in various directions, such as northwest in the northern portion of the central tablelands and in western New England. Nevertheless, a closer study of the topography reveals many interesting features, indicative of a grand unified control in the skeletal structure of the area under consideration. Thus, from an aeroplane (on the assumptions of physiological possibility and of clear visibility from an altitude say, of 100 to 200 miles, at which height all minor irregularities of form would disappear), it would be noted that:

i. Ocean depths occur to the east of the main highland zone, and a wide marine channel (Bass Strait) separates the continent from the island of Tasmania.

ii. Vast inland plains lie to the west of this highland zone.

iii. The highlands proper rarely abut directly on to the true oceanic slope, but generally are separated therefrom by coastal ranges (with intervening plains, valleys, or flats) or island lines, and continental shelf margin.

iv. The main trends of the western margin of the Pacific, the continental shelf, the shoreline and coastal strip, the coast ranges, the highlands themselves, and the eastern margin of the Great Inland Plains, are subparallel to parallel.

v. The main highlands themselves consist of plateaus varying markedly in height, as also in the angular value, and the direction, of inland or coastward slope.

The highland surfaces undulate, not only subparallel to their main axes, but also in a longitudinal direction, and their continuity as uplands is interrupted, in places, by broad transverse ranges or warps, and, in others, by deep broad structural gaps.

vi. The highlands, in many places, are bounded, or bordered, by higher broken ridges or plateaus, arranged *en échelon* and subparallel to each other. These highlands, or plateaus, with their not infrequent bordering ridges and ranges, present the general appearance of broad upland valleys, occupied with streams with sluggish courses in their middle portions, but which, sooner or later, plunge precipitately over actual ledges, or down steep tracks, into profound canyons, the number of which is so great as to cause the highland margins, especially on the ocean side, to take on the appearance of a network of gorges and wild ravines overlooked by retreating escarpments and high rambling spurs.

vii. High subparallel, but broken and interrupted, ranges, occur between the main highlands and the coast in places, as in Victoria, and are separated from the main highlands by broad and low-lying structural valleys.

This feature is repeated in New South Wales, on a smaller scale. In this State, however, the inter-range valleys are narrower and less persistent, being interrupted commonly by transverse ridges and ranges, and by the broken nature of the coastal ranges.

In Queensland this feature is indicated also by the alignment of certain island groups; of marine passages on the continental shelf; by coastal ranges, and the valleys between them and the more inland main irregular tablelands or highlands.

viii. These highlands attain their maximum elevations nearest to the places where the continental shelf is narrowest. The plateaus also, at such points, are of minimum width, whereas the highland zone, in general, is broadest and lowest opposite the points where the continental shelf attains its maximum width.

ix. The most pronounced break in the main range is Bass Strait, which is bounded, north and south, by the east-west ranges of Victoria and Tasmania, respectively, and the submerged longitudinal ridges forming the recent land links between Tasmania and Australia. Tasmania itself is a large island with bordering ranges, overlooking a high but depressed central plateau and a great longitudinal structural valley from Launceston to Hobart, trending parallel to the north-and-south plateaus and ridges of Tasmania.

These general statements may be amplified and modified somewhat. Thus the greatest heights of the

plateau are to be found at the great continental bend from a southerly direction in New South Wales to westerly in Victoria, with Mount Bogong (6,500 feet), Hotham (6,100 feet), and Feathertop (6,300 feet) in Victoria; and with Mt. Kosciusko (7,328 feet), Mt. Townsend (7,256 feet)—and many peaks 7,000 feet high in the same range—the Big Bogong (6,750 feet), and Mt. Bimberi (6,200 feet) in New South Wales, between Kosciusko and Canberra. In New England, in New South Wales, occur Mt. Kaputa (5,000 feet), Carey's Peak (5,000 feet), Bald Hill (5,300 feet), the northern wall of Guy Fawkes, eleven miles in length, and from 5,000 to 5,280 feet high, Ben Lomond (5,000 feet), and many others rising from a plateau level of 4,200 to 4,600 feet. In Northern Queensland, Mount Bellenden Ker and Bartle Frere exceed 5,000 feet, and are the highest points in the whole State. Opposite these maximum heights of the ranges, the continental shelf is narrowest; whereas it attains its maximum width in association with the wide lower plateaus drained by the lengthy Burdekin and Fitzroy Rivers.

With regard to the central or main highlands themselves, and their associated ranges, they may be described under three locality headings, namely, Victoria, New South Wales, and Queensland. The Queensland area is not so well known to the writer as that of the southern States, and attention is thus directed more particularly to the better-known areas. Nevertheless, the areas of Queensland visited by the writer, namely, the Darling Downs, Mount Morgan, the Townsville-Cairns belt, and the whole eastern coastline from New South Wales to Thursday Island, appear to be a natural geographical extension of the Victorian and New South Wales Highland and coastal zones.

Victoria.—The published reports of Fenner,¹ Gregory,² and Herman³ have been followed.

The Victorian Highlands comprise a group of plateaus and ranges, which have a subparallel trend with the coastal belt, and which rise to heights exceeding 6,000 feet in the east. They are connected with the high Grampians and other plateaus in the west by means of the narrow Pyrenees from the transverse structural gap traversed by the Sydney-Melbourne railway at Kilmore Gap. The eastern highlands exceed 2,000 feet in their central portions, as at Omeo, and are bordered by high ranges, especially on their northern aspect. Among these high margins are the Bogong, Feathertop, Hotham, and other lines. These high wide uplands are buttressed also with transverse ridges and higher plateaus.

South of the Victorian Highlands is the Great Valley of Victoria, which traverses the State from a point west of the Wannon Hills to localities east of the Gippsland Lakes. Eastwards it is continued as a one-sided valley to the New South Wales border. Port Philip itself is only a drowned portion of the Great Valley. This feature is bounded to the south by the Wannon Hills, the Otway (Coast) Ranges, the Barrabool Hills near Geelong, Arthur's Seat, and the highlands of the Mornington Peninsula, and the rugged ranges of southern Gippsland.

To the west and north of the main highlands lies the basin of the Murray River and the northwestern plains.

¹Fenner, C.: "Physiography of Victoria", *Proc. Pan-Pac. Sci. Congress* (Australia), 1923, pp. 719-721.

²Gregory, J. W.: "The Geography of Victoria", Whitcombe and Tombs, 1903.

³Herman, H.: "Economic Geology . . . of Victoria" (with contour map of State), *Handbook of Victoria*, Brit. Ass. Adv. Sci. (Australia), 1914.

Gregory states that the mountainous parts of Victoria are mainly formed of broad areas of dissected peneplains. The Otway Ranges and the Southern Gippsland hills also were once a peneplain which was raised with a general slope northward into the Great Valley.

New South Wales.—The accompanying notes have been prepared from reports made by Sussmilch,¹ and the writer.²

The geographer traversing the highlands of Victoria and New South Wales from the Australian Alps in Victoria to the Darling Downs in south-eastern Queensland, is impressed with the apparent geographic continuity of the various features throughout the many hundreds of miles crossed.

In the south the Australian Alps and the associated lower plateaus of Victoria pass insensibly into the higher Kosciusko Alps of New South Wales, while the eastern Victorian plateau, undulating and varying in height, sweeps unbroken from Victoria to the head of the Hunter River near Mudgee, between 32° and 33° Lat. S. High broken ranges border the plateau on the west, the most important being that which extends from the Pilot through Kosciusko and beyond Canberra to the north; another high area being that occurring at the head of the Lachlan River in the Bathurst district. To the east of the central plateau lie the broken, sub-parallel, offsetting ranges of the Gourock, Tindary, and other belts, extending from the southeast of Bombala

¹ Sussmilch, C. A.: "Main Topographical Features of New South Wales", *Proc. Pan-Pacific Sci. Congress* (Australia), 1923, pp. 721-726.

² Andrews, E. C.: "Geographical Unity of Eastern Australia", *Proc. Roy. Soc. N.S.W.*, 1910, pp. 420-480; *ibid.*, "Notes on a Model of New England", *Proc. Roy. Soc. N.S.W.*, 1912, pp. 143-155 (Pt. iii); *ibid.*, "Erosion and its Significance", *Proc. Roy. Soc. N.S.W.*, 1911, pp. 116-136.

to a point north of the Currockbilly Range. The plateau assumes a general slope in a northerly direction from the Blue Mountain, and Central, Tablelands, towards Mudgee, and the Main Divide takes on an appropriate swing inland at this locality.

Between the main ranges, to the south and northwest of Sydney, which vary in height from 3,500 to 7,300 feet, the central plateau occurs with heights varying generally from 1,800 to 2,600 feet, particularly along the area extending from Omeo, through Delegate, Bombala, Cooma, Queanbeyan, Canberra, Yass, and Goulburn. Transverse ranges tend to divide this main lower central portion, or plateau, into separate parks or plateaus, as for example, the Monaro Range or warp, south of Cooma, tying the Gourock near Nimmitabel with the Australian Alps near Kiandra. The Macquarie Range to the south of Bathurst is another example.

A marked structural gap in the higher plateau continuity occurs at the head of the Goulburn (Hunter) River. Here the plateau is slightly less than 2,000 feet in height at the Main Divide, with the general appearance of having been warped down from the higher areas of the Central Tablelands to the south and of New England to the north. Were it not for the existence of this marked undulation in the pitch of the plateau system, clean across the whole width of the upland area, there would appear to be a general coextension of New England, Central, and Southern, Tablelands, broken only by transverse and longitudinal warps or residuals.

Central New England is traversed by the main Northern Railway Line from Woolbrook to Wallangarra on the Queensland border. This undulating surface exceeds 3,000 feet in average altitude, and it is bordered by high, broken, and offsetting ranges to the east, rising

to heights varying from 4,000 to 5,300 feet. To the west it is bordered also by high broken ridges and plateaus.

This long, wide, central area, however, is not of uniform height, but is divided into two natural portions by a broad transverse warp with faulting of the plateau surface, between Armidale and Glen Innes, giving the appearance of a broad broken undulation of flattish top, rising about 1,000 feet above the 3,500 feet level, the extreme height of 5,000 feet being attained in Ben Lomond.

A very instructive series of features¹ is associated with the central or main New England tableland just described, in the nature of parallel or subparallel ranges, plateaus and depressions (valleys). One of these lower plateaus or depressions passes through Attunga, Barraba, Bingera, and Warialda, with the high Nandewar Range (5,000 feet) to the west; and the main New England Tableland to the east. To the east of the main New England tableland lie the great valleys drained by the long north and south arms of the Clarence and Richmond Rivers, bounded to the east again by high ranges.

The coastal region of New South Wales reveals the presence of large structural basins, with submeridional axes and with marked undulating pitch, as in the Nowra-Sydney-Newcastle, Port Stephens-Manning and Clarence-Richmond Districts. This coastal region, moreover, possesses a series of broken or relatively short undulations, subparallel to the main plateau trends, as south of Grafton, from the Manning to the Hunter, and along the South Coast. Transverse ranges, in many cases, cause these coast undulations to assume the

¹ Andrews, E. C.: "Notes on a Model of New England", *Proc. Roy. Soc. N.S.W.*, 1912, see Plate iii.

appearance of incomplete basins, as, for example, the ridge rising from sea-level at Cronulla to the Bulli Pass, and still farther south, but separated from the main Blue Mountain plateau to the west by the depression of Emu Plains, the Nepean River Basin, and the relatively low ground through Douglas Park, and thence southwards.

Queensland.—The main differences between the topography of Queensland and that of New South Wales and Victoria, appear to be quantitative rather than qualitative. The highlands of the more northern State are less mountainous; their elevation is less; their width is greater; and the broad transverse gaps which interrupt their longitudinal continuity are more pronounced. An examination of the records of the system of railways which connect coastal areas with interior plains suggests the existence of relatively low plateaus, not only in the Darling Downs area, but in a still more pronounced manner where the railway crosses the highlands between Rockhampton and Longreach, and between Townsville and Charters Towers. The Townsville-Cairns-Cooktown ranges resemble the southern plateaus more closely than do the areas drained by the Burdekin and Fitzroy Rivers between Townsville and Rockhampton. Sussmilch¹ describes the southern portion of the Queensland area as being a very natural extension of New England in New South Wales.

Europe.—The topography of Europe might be considered similarly, indicating the various Alpine systems therein to be a series of plateaus bordered by high sub-parallel ridges; separated by intermontane valleys; the

¹ Sussmilch, C. A.: "The Geomorphology of the Moreton District, Queensland: An Interpretation", *Proc. Roy. Soc. Queensland*, Vol. xlv, p. 104-131, 1933.

bordering plateaus or ranges looking out over foothills of sympathetic trend; while beyond these lie great inland plains to the north and the deep sea to the south. Beyond the North European, or Inland, Plain, lie the Scandinavian plateaus with their higher ridges.

SUMMARY OF TOPOGRAPHY.

From the foregoing brief statement as to the main topographic features of Asia, North America, South America, Australasia, and so on, it may be seen that the Eastern Australian Highlands, in a general way, are very similar to other great mountain systems of the world, in that they border a continent or great continental nucleus; that they have the general form of plateaus bordered by broken ranges; that they are traversed by transverse ridges or plateaus; that they are attended by depressions (or valleys) and broken ranges of subparallel trend, along the coastal areas and inland slopes; that they have forms appropriate to the associated continental shelf and ocean margin; and that, as such, they appear to constitute one great topographical unity among a whole series of other and related topographical (geographical) unities, such as the Appalachians, the Indian Ghats, the South African Plateaus, the Brazilian and Scandinavian Plateaus, the cordillera now occupying the site of the ancient Tethys of Eurasia; the Andes, and the North American cordillera.

EVIDENCE OF VOLCANIC DISTRIBUTION IN MODERN MOUNTAIN AREAS.

(a) *General Distribution.*—Volcanic action is associated generally with mountainous areas, whether along island arcs rising from the deep seas, or along high

continental cordillera forming marginal zones to the continents.

This statement needs amplification in some measure, for although in this note the general origin of modern mountains only is considered, nevertheless it is evident that these important facts of form did not spring from the ground overnight, as it were, but, as shown below, their history is bound up with the Tertiary stage of their development, their present outlines being due to late, or closing Tertiary activities, revived repeatedly, and to concomitant erosion by weathering and stream action.

In many instances, it is to be noted that existing high cordillera are not accompanied by active, or even recent, volcanoes; nevertheless, even in such cases, a study of the areas affected by the cordilleran movements indicates the existence of volcanoes, in active eruption, along the main lines of these great ranges, in the not distant past, such as the Miocene and Pliocene.

Suess has indicated that, in modern mountain zones (including island arcs), the active, or recent, volcanoes, do not occur on the earth undulation, or ridge, fronting the deep sea, but rather on an undulation, ridge, or range, behind the front one, or that which forms the wall or ramp nearest the deep sea, or ocean trench. Thus, in the northern United States, the recent volcanoes which ornament the Cascades do not rise from the Pacific Ocean as a front range, but lie behind the Coast Ranges with the Willamette Valley, Puget Sound, and other parallel structures (intermontane valleys) between. Excellent examples occur also in the West Indies, the Japanese and other eastern Asiatic island arcs, Alaska, the Netherland East Indies, and so on.

A study of the middle and late-Tertiary history of certain great ranges such as the Alps, the Himalaya, and the Tethyan system generally, indicates that this law of Suess held for these and similar regions in the middle and closing Tertiary stages. In other words, these zones, during the Tertiary, gave rise to the immediate ancestors of the mountains of to-day, either at or near the same sites, and volcanic action was common in the areas, and narrow arms of the sea were associated with the foothill areas of the youthful mountains. These mountain ranges were removed, later, in great measure, by earth movements and by erosion; then the land rose again in undulatory form; the sea retreated or the rising land advanced; and with this apparent recession of the Tertiary seas, the volcanoes moved closer to the receding, or shrinking, seas. Thus the volcanoes, once widespread in the Alpine system, are now confined to the borders of the Mediterranean Sea, and the volcanoes which, in the Tertiary, were ranged along the ancestral or Tertiary Himalaya, have disappeared with their old mountain foundations, and no active or recent volcanoes have been recorded from the Himalaya proper, but only along its natural seaward extensions, as in the Burmah area.

There is another law, or observed association, of volcanic distribution which is not recognized so generally. This is the peculiar occurrence of extensive basic lava flows over "stable" areas during, or about, the period of volcanic activity associated with the earlier divisions of the mountain building, that is, during the more vigorous stages of geanticline or cordilleran growth. Thus, side by side, as it were, with the "Sturm und Drang" of Himalayan beginnings, there occurred the repeated flooding, with fluidal basalt or other basic

lavas, of the neighbouring stable mass of Peninsular India, the depression of the Indo-Gangetic Plain separating them; the similar association of mountain "growing pains" along the Persia-Asia Minor Province and the "Harrass" or basalt sheets on the stable mass of Arabia beyond the depression of Mesopotamia and the Persian Gulf; the activities along the European Alpine zone and the flooding by basalt of the stable blocks of the Ireland-Scotland-Færoe areas, the Central Plateau of France, and so on; the wonderful volcanic display along the cordillera of the United States during the Laramide Revolution and the flooding of the "stable" block of the Yukon, British Columbia, the Columbia and Colorado Plateaus, and so on with enormous thicknesses of fluid basalt; the wealth of volcanic phenomena in the early (Tertiary) stage of Andean growth and the outpourings of basalt sheets in the "stable" areas of Patagonia and the Parana region; the great display of volcanic activity along the eastern island arcs of Asia and the basalt floods of Tertiary age in Siberia, Mongolia (Korea?), China, and Indo-China; the volcanic activity along the Great Rifts of Africa and the basalt flows of Abyssinia; the volcanic activity during mountain building in New Zealand, New Caledonia, New Guinea; and the Tertiary basalt floods of the highland area of Eastern Australia.

Although these basalt-flooded regions of "stable" land are now plateaus, or upland valleys, of low to moderate height, nevertheless the evidence is that, at the time of their visitation by basic lavas, they were depressed or sinking areas.

Perhaps a brief reference to some of the main areas mentioned above in this connection may tend to make this important empiric law more easily appreciated.

Tethyan Area (Asia Minor to China via the Thibetan Region).

The Himalaya may be taken as the type. In this immense region, igneous intrusions and volcanic activities on a grand scale are reported, in successive stages, during the closing Cretaceous, the middle, and later Tertiary. The Cretaceous and Tertiary sediments also have suffered, markedly, from the action of folding. The igneous phenomena are reported to be both of the plutonic and the ordinary volcanic type. Movements still later in date gave to the Himalaya their present form. Neither modern nor recent volcanoes occur in the Himalaya to-day, and it would appear that, as the narrow Tertiary continental sea of the Himalayan region retreated east and west to the main ocean, so actual volcanic activity declined in the mighty range.

The enormous display of basaltic rock known as the "Deccan Trap" occurs in Peninsular India, and is related intimately, in time, with the earlier explosive activity of volcanoes and the plutonic intrusions which marked the very youth of Himalayan growth. The Deccan "Trap" covers an area of 200,000 square miles, approximately, underlain immediately by stable areas of very ancient rocks. The "Traps", which exceed 6,000 feet in total thickness in places, extended formerly over an area much larger than that occupied by them to-day. They are considered, from a study of their fossil contents, to have commenced in the closing Cretaceous and to belong mainly to the Tertiary.

The enormous basalt flows of Arabia, known as the "Harras", are related to the great mountain building and volcanic activity, in the early Tertiary of Asia Minor, Armenia, and Persia, much as the Deccan

"Traps" are to the Himalayan elevations and earlier volcanic and plutonic activities.

The American cordillera reveal similar histories of plutonic intrusions, volcanic explosive activity, and pronounced folding during the Tertiary Period, while on certain associated "stable" areas great successive deluges of basic lava took place during the Tertiary, apparently the mid-Tertiary.

The close association also of the Tertiary Siberian basic lava floods with the plutonic, volcanic, and folding activities during the Tertiary along the Thian Shan, Alai, Ala Tau, and other strong mountain lines, is significant, as is also the youthful mountain growth, with its accompaniment of igneous intrusions, along the great insular arcs of Asia, with the deluges of fluidal basic lava recorded from Mongolia, Korea, China, and south-eastern Asia.

The Andean Region.

The very numerous volcanoes of the Andean zones do not occur on the coastal ranges proper, but rather on the Maritime or Western cordillera, where they form a very considerable portion of the range itself. The flows, according to Bowman,¹ amount in places to more than one hundred superimposed sheets, having a total thickness, in places, of 7,000 feet approximately. They appear to be post-Cretaceous in age, and volcanic activity appears to have been continuous, at least since the beginning of middle Tertiary.

At the great Bolivian and Peruvian massifs, there appears to have been some flooding by fluidal basic lavas, but the main sheet outpourings of basic lavas appear to have taken place on the associated "stable" areas of Patagonia and the Parana areas.

¹ Bowman, Isaiah: "The Andes of Southern Peru", p. 199, 1916.
H—November 1, 1933.

North America.

Broadly, it may be stated that the present location of the more stable areas (the Greater Colorado Plateau Province excepted) of the western United States, Canada, and Alaska, was a long enduring and compound geosyncline, which received vast accumulations of sediments for geological ages. During the Mesozoic¹ a great geanticline rose gradually along the axis of this depression. With the growth of the geanticline, its structure became more unstable with volcanic action as a common accompaniment. At the close of the Jurassic, the rocks of the area were strongly folded, and sedimentation retreated to subparallel geosynclines which now came into being both east and west of the new compound cordillera (geanticline).

At the close of the Cretaceous the sediments of the eastern geosyncline were elevated to make the earlier Rocky Mountain system. In this process of mountain making, volcanic action was a common accompaniment. Sedimentation in marine geosynclines at this stage was confined mainly to the parallel seaways on the Pacific side, and later elevation of this more coastal region resulted in the present coastal cordillera.

In all these geanticline (with appropriate accompanying geosynclines) growths the definite tendency existed for the volcanic foci to follow the seaways and to disappear from areas whose former associated seaways had been obliterated.

During the great display of volcanism in the Rocky Mountains and the Pacific coastal provinces, the Interior Plateau, or Inter-Cordilleran, areas of the United States

¹Schuchert, C.: "Sites and Nature of the North American Geosynclines", Presidential Address, *Proc. Geol. Soc. America*, Vol. 34, 1923, p. 151.

and of Canada were flooded with basic lavas; the localities most affected thus being the Columbia Plateau, British Columbia and Yukon Territory. These fluidal basic laval flows exceed 4,000 feet in total thickness in places.

In all these areas Suess' law may be observed to be followed. The volcanoes are not situated on the first, or frontal, earth undulation facing the deep sea, but on a parallel, but not the most rearward undulation (ridge, range, or cordillera). Thus, as in the Bolivian knot, or massif, where one finds the volcanoes on the Cordillera Occidental and Central Cordillera, but not on the grand Cochobamba group farther east, so one expects to find the North American volcanoes on the second and supporting lines of the Pacific Ranges (Cascades and so on), rather than along the Rocky Mountains and associated belts.

The arrangement of the basic laval flows is significant, inasmuch as, in North America, they occur on the stable block of Lawson's "Cordilleran Shield", for the United States, and in Brock's "Interior Plateaus", for Canada, rather than in Labrador and the Appalachian Region; and, for South America, they occur in Patagonia and Parana areas rather than on the Brazilian Plateau. This point is reserved for discussion in a forthcoming paper on the "Growth of the Continents". In every instance, however, as cited above (for Europe and Africa also), the volcanoes proper are massed together along the very unstable portions of the earth's crust, whereas the basalt floods occurred on earth blocks of great relative stability.

New Guinea, New Zealand, and Eastern Australia.

The great compound island arc, or festoon, passing through New Guinea, New Britain, New Ireland, The

Solomons, The New Hebrides, and New Zealand, indicates a long succession of volcanic activities during Tertiary and post-Tertiary time.

According to Stanley,¹ "The Territory of New Guinea and Papua constitutes a wonderful field for volcanic research. Volcanic outbursts, on a grand scale, have occurred in association with intense folding within moderately recent geological times."

Stanley distinguishes four phases of volcanic activity: one pre-Miocene; one commencing in Miocene time; another reaching its maximum in Pliocene time; and a fourth extending from early Pleistocene until the present day. The latest stage has been productive of the more pronounced basic lavas, such as olivine basalts. New Britain, New Ireland, The Solomons, and other related groups, afford examples also of great volcanic activities along this compound insular arc in the various divisions of Tertiary and post-Tertiary time.

New Zealand.—The volcanic belt of New Zealand traverses the North Island through its central portions, as also the western New Plymouth and Auckland divisions. The central volcanic foci are situated behind or inland of the compound ranges of the Rimutaka-Ruahine, and the subparallel mountain ranges lying to the east.

Active and recent volcanoes are not recorded from the South Island, which comprises the compound Alpine structures mentioned under "Topography", but abundant Tertiary to sub-recent volcanic centres are recorded from the eastern margins of the Otago and Canterbury provinces.

¹ Stanley, Evan R.: "Volcanic Action in New Guinea", *Proc. Second Pan-Pac. Sci. Congress* (Australia), 1923, Vol. i, p. 830.

Eastern Australia has been flooded apparently in middle and late Tertiary time with fluidal basic lavas.¹ In the report cited, the lavas are described as the Older and Newer Volcanics. The age (or ages) of the flows is not known with certainty, but palæobotanical evidence points to a long continued activity for the extrusions, probably commencing in the mid-Tertiary with recrudescences in later Tertiary.

These basaltic and other basic lava types are confined to what is now the plateau, or highland regions (including the coastal and inland slopes of the plateaus and foothills or subsidiary hills), and have not been recorded from the western or central inland areas. The plateaus themselves, however, are capped in many places with very wide sheets of "basalt" which, in turn, overlie "deep leads" or buried river deposits.² They are recorded from Tasmania, the highlands and coastal areas of Victoria; from Monaro, the South Coast, the Central Plateaus, the Hunter-Macquarie area, New England, and associated coastal regions in New South Wales; from the Darling Downs, the Central and Cairns Tableland areas, and various coastal areas in eastern Queensland. They occur to-day at heights varying from points below sea-level to lava uplands from 2,000 to 6,000 feet above sea-level, where they are known, as in Victoria, as "High Plains", or as high "Tops" in New England. They have been dissected in a pronounced manner by stream action, and, in many places on the plateaus, they occupy the highest positions within wide shallow valleys of erosion, whereas, at the time of their deposition, the associated "deep

¹ Andrews, E. C.: "Geographical Unity of Eastern Australia", *Proc. Roy. Soc. N.S.W.*, 1910, pp. 448 ff.

² Another interesting fact is the absence from the central and western inland areas of the "deep leads".

leads" (river gravels)—and which now in common with the "basalts" overtop the upland valleys—indicate that they occupied the lowest points of the landscape. The bases of the canyons which have cut through them are as much, in places, as three or four thousand feet below them. The canyons themselves are later than the broad shallow valleys excavated in the basalts; nevertheless their heads retreat along the old mature valley stream channels. The basalts form the rims to the profound canyons in many instances.

A study of the association of the "leads" and the basalt sheets indicates that the basalts were discharged over a sinking or depressed area, and at a period in Tertiary time prior to the formation of the present plateaus of Eastern Australia.

Summary.

In all the instances recorded above certain significant features appear to be possessed in common:

1. In the lofty ranges, the younger geological formations, such as the Cretaceous and the Tertiary, are intensely folded.
2. These areas of deformation were the seats of pronounced plutonic intrusions and of Tertiary to Recent volcanic activity. The extrusions appear to be mainly of the explosive type.
3. These same areas are still quite unstable.
4. The basalt, with other basic lava-deluges, occurred, apparently, about the time when the great ranges were in their earlier stages of growth.
5. The basic lavas were, relatively, very fluidal, and appear to have been mainly of the type which "welled out", with relative quietness, to the surface.
6. The fluid basic types were extended over areas of great relative "stability", these areas, in many cases, consisting of ancient rocks. In some instances even ancient rocks composing the lava basement have not been folded; in others, the rocks have been folded in a marked manner.
7. The areas flooded with the fluidal basic lavas appear to have been relatively depressed at the time of basalt visitation, although to-day they commonly occupy plateau or upland areas.

These facts of distribution in time, and of variation in lava types, suggest strongly that the ordinary intrusive

and volcanic activity of the youthful ranges was related structurally to the basic lava flooding of the long established "stable" areas in the same great region.

There would appear thus to be some causal and practically world-wide relation, on the one hand, between the earlier growth of the great Alpine ranges, or cordillera, of the world in very unstable areas with their plutonic and volcanic accompaniments, and, on the other hand, with the vast outpourings of fluidal basic lavas, in the early, middle and late Tertiary period, over relatively stable areas. The indication is that the contrasted areas, under pressure of great earth activities, were undergoing mutual balancing with each other, extravasation of basic lava characterizing the strong areas of the old folded systems and plutonic intrusions with explosive volcanic activity characterizing the yielding of the weaker unstable areas.

PENEPLAINS, AND THE STRUCTURE OF MODERN MOUNTAINS.

This report deals with the structure of modern mountains only. The history of their forerunners is a complicated one, involving an inquiry into the growth in stability of continental masses, and has been selected as the subject of a later note.

The areas selected for illustration as types of modern mountain structure are those which have been described above topographically, and comprise:

- (a) The main Himalayan and associated ranges and plateaus with the Ghats.
- (b) The Andes, with Brazil.
- (c) The North American cordillera, with the Appalachians.
- (d) New Guinea, New Zealand, with Eastern Australia.

To these types the Persian-Asia Minor ranges and plateaus with Syria and Arabia; the European Alpine and plateau areas with the Scandinavian highlands; and the African ranges and plateaus, conform.

All agree in conforming to a few broad principles, although considerable divergence of opinion is held among students as to the exact values to be assigned to the time factor involved in the age of each; the importance of vertical uplift as compared with folding; to warping as compared with faulting; to the heights, under varying conditions, above sea-level at which a peneplain may be produced, and the measure of uplift experienced by an old worn-down surface when elevated into a plateau or mountain range; and so on. It is to be noted, however, that the actual mountain ranges existing to-day are only very youthful forms, being the result, in most instances, of elevation of undulatory nature, during late to closing Tertiary time, of low-lying surfaces of erosion, developed (during some division of Tertiary time) within the ranges belonging to a stage immediately antecedent to those of the present forms. Thus mountains generally tend to be undulating plateaus. In localities where elevation is not pronounced, the tendency is to form broad or wide plateaus only moderately diversified with corrugations, or undulations. In those places, on the other hand, where elevation is very pronounced, there is a definite tendency for the high plateau to flow out on itself, with the production thus of great earth wrinkles or undulations. Volcanic action, moreover, tends to modify the broad profiles of undulatory (differential) uplift, and high ranges tend also to mould themselves with sympathetic axial directions on to neighbouring nuclei of relatively stable rocks. (Examples: The Colorado Plateaus which are margined by the Rocky Mountains, the Uinta Mountains, and other undulating range forms).

(a) *The Greater Indian and Thibetan Region.*

These areas are presumed to include Thibet and the Pamirs, with their lofty bordering ranges, together with a portion of Turkestan.

(i) *The Himalaya.*—Peninsular India has been entirely free from folding of any importance since late Pre-Cambrian, if not indeed since much earlier Pre-Cambrian. No marine fossils occur in the Peninsula earlier than Jurassic and Cretaceous, and these are reported to occur only along the more coastal areas. In the Himalaya, on the other hand, from Cambrian to Eocene time inclusive, the fossil sequence is almost entirely marine. In other words, during the greater part of that long geological period of time, the Himalaya existed as a marine trough or geosyncline. Between the crumpled younger beds of the Himalaya and the undisturbed rocks of the Peninsula lies the deep Indo-Gangetic basin (plain), or trough, filled with recent alluvium. The elevation and crushing of the earlier Tertiary marine beds—and now occurring as much as 20,000 feet above sea-level—commenced apparently in the Miocene and continued into the Pliocene. The Northern Himalayas (Thibetan zone) consist mainly of fossiliferous Palæozoic and Mesozoic, the Central and Lower Himalaya of crystalline, metamorphic, and other rocks; while the southern, comprising the sub-Himalaya, consists of Tertiary beds, especially upper Tertiary sediments. (The Salt Range includes ancient sediments.)

As the Himalaya rose again, in the later stages, it crushed and folded the beds of its own stream waste (Siwaliks) in the process. "It appears, therefore, that the Himalaya grew southwards in a series of stages. A reversed fault was formed at the foot of the chain, and upon this fault the mountains were pushed forward over the beds deposited at their base, crumpling and folding

them in the process, and forming a sub-Himalayan ridge in front of the main chain. After a time a new fault originated at the foot of the sub-Himalayan zone thus raised, which now became part of the Himalaya themselves, and a new sub-Himalayan chain was formed in front of the previous one in time the deposits of the present Indo-Gangetic plain will be involved in the folds.”¹

(ii) *Hindu Kush*.—This vast earth bulwark is a natural continuation westward of the lofty bordering ranges of Thibet and the Pamirs. Holdich,² in describing it, states that “successive flexures or ridges are ranged in more or less parallel lines, and from between the bands of hard unyielding rock of older formation the soft beds of recent shale have been washed out. . . The Hindu Kush is, in fact, but the face of a great upheaved mass of plateau land lying beyond it northwards, just as the Himalaya forms the southern face of the great tableland of Thibet, and its general physiography, exhibiting long, narrow, lateral valleys and transverse lines of ‘antecedent’ drainage, is similar.”

(iii) *Turkestan*.—Huntington’s notes on the structure of the Thian Shan and other ranges (with associated basins), in Turkestan, are specially illuminating in connection with the observed structure of modern mountain profiles. Of all the great mountainous areas examined by him in that region, he points out³ that they may be regarded as uplifted, and more or less dissected, portions of an earlier low-lying plain (or plains) of erosion. The traces of the old peneplain surface are still evident in

¹ Lake, Philip: “Himalaya”, *Encycl. Brit.*, Ed. xi.

² Holdich, Sir Thomas H.: “Hindu Kush”, *Encycl. Brit.*, Ed. xi.

³ Huntington, Ellsworth: “Explorations in Turkestan”, Pumpelly Expedition, *Carnegie Inst. Publication*, 1905, pp. 167-171.

the hard Palæozoic formations of the lofty plateaus and may be detected even in the softer Tertiary deposits of the region. Some of the mountain passes are in the soft upper members of the Tertiary, although occurring at elevations exceeding 12,000 feet. He points out the existence of the elevated peneplain forming the general surface of the Thian Shan, the crests of the Alai, and the Pamirs, at heights varying from 15,000 to 20,000 feet.

“Although the age of the peneplain is not closely fixed by the evidence of fossils, it may be referred to the end of the Tertiary, because its erosion was completed after practically the whole Tertiary series of the region had been laid down and warped.”¹

When the great Tertiary peneplain of this region was elevated to form the lofty ranges of the present day, the movement was in the nature of warping by which it was deformed into basins, large and small, with intervening swells and ridges. The uplift was very considerable, “for some of the ridges, such as the main crests of the Thian Shan plateau, and of the Alai Range, were raised over 10,000 feet above the bottoms of the neighbouring basins.”

These irregular warpings did not seem to have initiated new lines of mountain ranges, but to have repeated, or strengthened, previous Tertiary belts or zones. The Quaternary basins appear also to be revivals of earlier basins, and in them the sediments are thicker in the more central portions, becoming thinner towards the margins, where they are also more warped or bent “as though the edges of the basins had been gradually raised out of the area of deposition.” The harder rocks, such as the granitoid types, and the Palæozoic limestones, formed the

¹ *Ibid.*, p. 168.

uplands in the peneplain stage preceding the later, or post-Tertiary, uplift, as they had done for ages and as they do to-day.

In illustration of this definite tendency for the country to rise in enormous warpings or flat-topped undulations, which latter tend to spread and crush, or involve, the adjacent gravels and alluvium in the process, Huntington cites a typical case.¹ "In the Thian Shan plateau, ten or fifteen miles from the edge of the Quaternary plain of the Kashgar basin, the conglomerate at the top of the Tertiary is highly folded and very hard, but as the same stratum is traced southward and westward, it becomes softer and less folded, until finally it seems to run into the soft gravel of very recent date. . . . Moreover, the old resistant conglomerate of the Thian Shan region has been smoothly base-levelled since its severe folding was completed, while the gentle folds of the soft young gravel have only been dissected by narrow valleys, which have not yet produced a maximum of relief. This seems to mean that somewhere in Tertiary time the border of the Kashgar basin was fifteen or twenty miles north of its present location, and was a place of heavy gravel deposition. Then a small fold developed along the border, lifting up part of the gravels and causing the accelerated streams to deposit their load of pebbles farther towards the centre of the basin, where playas had formerly deposited silt. Later, another fold was developed and the gravels once more advanced, and so on, by steps which were perhaps too slow to be noticed. The older gravels were compressed and hardened into conglomerates, and their upper portions were worn down to the smooth grade of the Tertiary peneplain. A similar experience befell all the underlying formations. Each of them, and

¹ *Ibid.*, pp. 170-171.

the peneplain as well, represents not a certain time, but a stage in development, and some of the stages are not yet completed."

Of the general structure of the present Thian Shan plateau, Huntington points out that it is essentially a very broad anticline of the Uinta type, where the sides are monoclines and the top more or less flat. The anticline is undulating even on top, the crests being broad ridges from 13,000 to 15,000 feet in height and the intervening troughs 10,000 to 12,000 feet.

Sven Hedin's accounts of the Himalayan-Thibetan-Turkestan areas, together with his published illustrations, are independent, but confirmatory, pictures of the structures of these mighty Asiatic features.

It may be seen thus that the Himalayas simply repeat on a grander scale, and in more intensified manner, the structure of the Thian Shan, Alai, Trans-Alai, and other associated ranges. In all may be noted the warped, or broadly-anticlinal, uplift of extensive surfaces of erosion produced in late-geological time. In proportion as the uplift was accentuated or pronounced, so the earth undulation produced tended to sag on itself, becoming depressed in long axial troughs on its summit and being rucked at the margins with actual advance outwards towards the deep bordering structural valleys, accompanied by folding and faulting of its own waste sheets in the process.

This point it is important to note when dealing with the question of the relative parts played in mountain building or structure, by isostasy and crustal strength, because of the light it throws on the appearance and structure of wide lofty plateaus and of upland surfaces existing only at inconsiderable heights above sea-level.

The Ghats.—It may seem inadvisable to attempt a serious examination of the possible resemblances between the Himalaya and the Ghats, but the student may have perceived already that the facts of observation indicate the points of resemblance existing between them, both being plateaus, one in an unstable, the other in a relatively very stable area; the one having been elevated so considerably that it has spread laterally by "rock flowage" on its own foundations, with the production thus of wrinklins and longer axial depressions along the plateaus proper and with crushing, folding, and faulting of its own waste sheets, the other not having been elevated sufficiently to give "rock flowage" an opportunity to be so spectacular a feature as in the Himalaya, especially when such moderate elevation has occurred in dense, powerful, crystalline structures, whose powers of resistance are at a maximum.

(b) *The Andes.*

The descriptions of the Andean forms by Berry and Singewald, Bowman, H. E. Gregory, Holdich, and others, suggest strongly that the Andean areas have had a history closely resembling that of the great Asiatic types noted above. Marine rocks of Cretaceous age occur throughout the high plateaus and are of common occurrence there as strongly folded types. Sediments of the Cretaceous, as also associated older complexes, were elevated to form the ancestral Andes; these were eroded in stages to form a peneplain, and then raised intermittently in broadly-anticlinal form with the development of subparallel and longitudinal undulations or corrugations. Tertiary rocks, derived from the waste of growing ranges, have been folded along the expanding margins of the cordillera during later revivals of elevation, the final great warping action occurring, probably,

about the closing Tertiary. Bowman¹ considers that a great fault, with a scarp four thousand feet in height, approximately, terminates the Andes, on the eastern border of Peru, but his general descriptions suggest that the structure partakes rather of the nature of a large undulation modified by strong faulting. Later "moderate elevation was followed by an interval sufficiently long to develop a mature topography. Differential uplift and faulting raised the ranges in the late-Tertiary approximately to their present, or even greater, altitudes, and resulted in the formation of great thicknesses of continental basins, such as those of the intermontane basins, of which the Bolivian plateau is the most noticeable and best authenticated, and of warped peneplains bordering the Andes on the east in Bolivia and in Argentina. In some cases these deposits, which are Pliocene in age, wherever they have been dated palæontologically, are folded. In other cases they have undergone little or no deformation, as in the widespread shell and plant-bearing Pebas beds of eastern Peru, which are also present in the Marañon Valley behind the front range. In all cases these Pliocene plant beds in the mountains from Columbia southwards have been uplifted at least 1,500 meters, and probably much more, and in at least one instance at the southern end of the system, marine Pliocene has been elevated over a mile. . . . Nowhere in the Andes have we seen evidence of great horizontal movements or low-angled fault or gliding planes such as characterize the Alpine type of modern structure. Everywhere in the Andes vertical movements are the dominant features, and these completely mask any horizontal movements."²

¹ "Andes of Southern Peru", p. 241.

² Berry, E. W., and Singewald, J. T.: "The Tectonic History of Western South America", *Proc. Third Pan-Pac. Sci. Cong.* (Tokyo), 1926, Vol. i, pp. 438-439.

Brazil.—The notes supplied above concerning the topography of the Brazilian plateaus and ranges suggest strongly that they are peneplains, or surfaces of erosion which have been elevated in late geological time, and that the area is a homologue of the broader Andes, due allowance being made for the width of the area affected, the relative insignificance of the measure of undulatory elevation, together with the strength and rigidity of the massive rock structures involved.

(c) *North America.*

The Western Cordillera. The accompanying notes on the cordillera have been prepared from published reports by Brock,¹ Fenneman,² Lawson,³ and others.⁴

The cordilleran area includes several portions, among which may be cited the Vancouver, Coast, Columbia, and Selkirk, Mountains in Canada, and the Basin, Cascade, and Sierra Nevada Ranges, together with the Columbia Plateau and Cœur d'Alene Provinces in the United States. These more central portions of the North American cordilleran area may be considered as having been converted into great mountainous belts, accompanied with widespread foldings and intrusions by plutonic rocks during Jurassic time. The ranges thus produced are disposed generally parallel to the present coast with the exception of those in the vicinity of the ancient nucleus of Colorado and neighbouring areas to which Jurassic

¹ Brock, R. W.: "Structure of the Pacific Region of Canada", *Proc. Sec. Pan-Pac. Sci. Cong.* (Australia), 1923, pp. 776-783.

² Fenneman, N. M.: "Physiography of Western United States", McGraw Hill, 1931.

³ Lawson, A. C.: "The Cordilleran Shield", *Third Pan-Pac. Sci. Cong.* (Tokyo), 1926, pp. 371-388.

⁴ "Alaska", *Encycl. Brit.*, Ed. xi (1910).

mountains were moulded where the two areas came into touch with each other. At a later stage, a low-lying area was produced over the site of the ancient Coloradan nucleus, within which erosion developed a peneplain, or an approximation to one, where the Basin Province now is, and extending thence north throughout Oregon, Idaho, Western Montana, and the Interior Plateaus of Canada and Alaska. A deep seaway existed to the immediate east, in which sediments of an enormous thickness had accumulated since Pre-Cambrian time.

At the close of Cretaceous time, and throughout the Tertiary, in great measure, these old sea areas were elevated by stages into mighty compound ranges. Where the sediments were thick the rocks were much folded and faulted, but where the sediments were much thinner, the sea floor was uplifted in broad compound anticlines. Thus came into being the earlier main ranges of the Rocky Mountain system.

The accompanying notes by Brock¹ on the structure of the eastern ranges are very instructive in any attempt to appreciate the underlying causes of modern and recent mountain making.

"The structural lines are parallel to those of the Jurassic mountains. What appears to be normal structure in the Rockies is a fold beginning at each end as an open anticline, but rapidly becoming closed, then overturned to the east, then recumbent, and finally, in the centre, becoming fractured and overthrust. In extreme cases, the overthrust which . . . is to the east, amounts to many miles. Where pressure is intense, the resultant structure is a succession of overlapping overthrust blocks.

"There is a definite relationship between mountain range and anticlinal fold, and of altitude to folding and faulting. On the eastern face of the Rockies, the lines of fold are arranged *en échelon*, generally stepping westward, so that in the north the Franklin Mountains lie east of the Mackenzie River. . . ."

¹ "Structure of the Pacific Region of Canada", *Proc. Second Pan-Pac. Sci. Cong.* (Australia), 1923, pp. 781-782.

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The Coastal Ranges have had a more complex history, dating from the Jurassic, and being renewed at least in part throughout Tertiary and Recent time. These areas, in great measure, are still unstable. According to Lawson: "The structures of the Coastal Mountains comprise: (1) Broad anticlinal arching of the pre-Cretaceous surface; (2) open folding of Cretaceous and Tertiary strata; (3) close folds with local overturns . . . (4) large overthrusts, the direction of apparent overthrusting being seaward."

Lawson furthermore concludes that the Rocky Mountains and the Coastal Mountains have been built round, or moulded to, the Jurasside Shield, and by their upbuilding have determined its limits.

A careful study of the publications of Fenneman, Lawson and Brock indicates the origin of most of the present great ranges as warped, folded and faulted "peneplains", developed alike in volcanic ejectments, basalt deluges, massive plutonics, or sediments (folded or sub-horizontal).

The Appalachian Mountains.—The article by Davis¹ has been followed in the main, although modifications of his conclusions have been proposed in more recent years, concerning the age and nature of certain warped "peneplains". Generally, there appears to be a tendency to decrease the earlier estimates of age for the formation of the great erosional surfaces concerned.

The mountain system "consists essentially of two belts, one on the south-east, chiefly of ancient and greatly-deformed crystalline rocks, the other on the north-west, a heavy series of folded Palæozoic strata; and with these it will be convenient to associate a third belt, farther north-west, consisting of the same

¹ Davis, W. M.: "United States", Physiography, *Encycl. Brit.*, Ed. xi.

Palæozoic strata lying essentially horizontal and constituting the Appalachian plateau."

Great ranges were formed in the areas now occupied by the highly compressed and the crystalline series during the earlier, later, and the closing Palæozoic. Towards the close of the Tertiary period, two great surfaces of erosion had been produced in the area, one almost complete, with scattered residuals, the other (and later) being incomplete and consisting of very broad valleys excavated within the older warped peneplain surface. This compound erosional form, in turn, was arched or warped in later time, to form plateaus, or broad upland valleys, of moderate to considerable height, and which are now traversed by deep youthful valleys.

These features may be traced, more or less continuously, for 1,500 to 2,000 miles within the United States and Canadian areas. The height of the plateau, in the crystalline belt of the middle Appalachians, is greatest along the inner or north-western border of the belt.

The general warping action is shown also by the attitude of the piedmont belt which sweeps round the east and southerly aspects of the ranges, and a significant fact in mountain structure also is the statement by Davis that:

"The boundary between the mountains and the piedmont belt is called the Blue Ridge all along its length; and although the name is fairly appropriate in northern Virginia, it is not deserved in the Carolinas, where the 'ridge' is only an escarpment descending abruptly 1,000 or 1,500 feet from the valleys of the mountain belt to the rolling uplands of the piedmont belt; and as such it is a feature of unusual occurrence. . . . The piedmont belt merges south-eastward into the coastal plain."

(d) New Guinea, New Zealand, and Eastern Australia.

The accompanying brief notes on the mountain structures of these three important areas have been sum-

marized mainly from the reports by Stanley¹ and Zwierzycki² for New Guinea; by Marshall³ and Morgan⁴ for New Zealand, and by Andrews,⁵ Fenner,⁶ and Sussmilch⁷ for Eastern Australia.

New Guinea.—In this area a pronounced movement of folding appears to have given rise to compound and subparallel earth undulations (geanticlines) in New Guinea during Tertiary time. At a later period these ranges were reduced to the peneplain stage, and the erosional surfaces thus produced were raised during closing Tertiary or early Pleistocene time to form lofty compound plateaus or geanticlines, broken here and there by transverse gaps mainly arranged *en échelon*. Thus arose the giant structures of the northern coastal region (13,000 feet maximum elevation), as also the lofty main central mountain axis (16,000 feet). Between these massive compound ranges lies the long interrupted depression disposed longitudinally from end to end of the island. According to Zwierzycki, a reverberation of the great longitudinal northern depression is to be found in the existence of another depression along the more southern portion of the island. He draws attention also to the folding and faulting and overturning attendant on the latest great elevations.

¹ Stanley, E. R.: "The Structure of New Guinea", *Proc. Pan-Pac. Sci. Congress* (Australia), 1923, pp. 764-771.

² Zwierzycki, J.: "Tectonic Movements in the East Indian Archipelago", *Proc. Fourth Pan-Pac. Sci. Congress* (Java), 1929, Vol. i, pp. 279-281.

³ Marshall, P.: "Geography of New Zealand", pp. 93-106.

⁴ Morgan, P. G.: "Structure of New Zealand", *Proc. Sec. Pan-Pac. Sci. Cong.* (Australia), 1923, pp. 743-745.

⁵ Andrews, E. C.: "Geographic Unity of Eastern Australia", *Proc. Roy. Soc. N.S.W.*, 1910, pp. 420-479.

⁶ Fenner, C. E.: "The Physiography of Victoria", *Proc. Sec. Pan-Pac. Sci. Cong.* (Australia), 1923, pp. 719-720.

⁷ Sussmilch, C. A.: "Main Topographical Features of New South Wales", *Proc. Sec. Pan-Pac. Sci. Cong.* (Australia), 1923, pp. 721-725.

New Zealand.—The mountains of this area appear to have had a long and complex history, elevation being accompanied by folding and faulting. Peneplanation appears to have ensued in Tertiary time, and the present mountain ranges represent the warping of this erosion surface to form lofty, continuous, and broken, ranges, separated by structural valleys. Many mountain ranges appear to be of the nature of faulted blocks which have been warped or folded themselves, and which have crushed their own outwash gravels and other sediments in a “spreading” action induced within them by rock flowage. These earth undulations and faulted blocks¹ have been much modified in form by the action of ordinary streams and by glacial action.

Eastern Australia.—A comparison of the structure of Extra-Australian mountains, with the forms obtaining in the Eastern Australian highland regions, sheds a considerable light upon the structure of the latter. Many structures in Eastern Australia which are significant (but not of topographic prominence because of the pronounced factor of rock strength and rigidity present) may be detected by such comparison which otherwise would appear to be but freak forms or mere peculiarities resulting from differential erosion.

The form of the plateaus which constitute the main highlands suggests that they arise from the elevation, by warping and gentle arching, of a great surface of erosion of Tertiary age. This erosion surface is not a

¹ The recent close studies of W. N. Benson have tended to confirm the careful observations on the occurrence of faulting on an immense scale in New Zealand made by C. A. Cotton. Benson has been enabled to indicate also the very marked manner in which “peneplains” or erosional surfaces in New Zealand have been warped, faulted, and folded again, in later Tertiary time probably. (Personal communication.) Benson’s whole sequence of observations on mountain-making in New Zealand is most instructive.

simple feature, but appears to be the result of two or more cycles of erosion, the earlier one resulting in a widespread peneplain of incomplete development which was warped later and relatively shallow but youthful valleys incised therein. These were depressed in turn, filled with stream wash and then flooded in many places, and several times in succession, with highly fluid basalt. The new surface was elevated by warping and an incomplete peneplain was developed therein with the production of very broad mature to old age valleys even near the Great Divide between the coastal and inland drainage. During the Kosciusko movement, probably from closing Tertiary to the present time (consisting of many revivals of movement), this complex low-lying area of erosion was warped to its main present position.

Although the mountains, or plateaus, are recognized, generally, as warped surfaces of erosion (developed at relatively low levels above sea-level), nevertheless there are several interesting points which necessitate some special explanation, or modification, of this statement as to simplicity of structure.

These features include:

1. The general surface slopes of the plateaus and of their margins.
2. The longitudinal valleys of the plateaus.
3. The irregular, and broken, bordering ranges and hills.
4. The side-stepping arrangement of plateau ranges and valleys.
5. The transverse ranges of the plateaus.
6. The associated transverse and longitudinal coastal ranges.

1. *The plateau surfaces and marginal slopes.*—To the casual observer, the mountain areas appear, from the

coastal region, as a chaotic assemblage of hills and ramparts, which have been modified to such an extent by retreat of escarpments due to stream erosion as to be utterly devoid of orderly arrangement. In the areas of folded rocks and dense intrusive granitoids, this appearance of an uplifted mass, or plateau, bitten deeply into by headward stream erosion, is accentuated. It is these areas, particularly, in which the student fails to discover signs of distinct "structures". There are, however, other and neighbouring areas, but coextensive with these, where the successive phases or stages in undulatory uplift may be detected with ease, and the general symmetry and continuity of the plateau surfaces and alignments indicate a common origin for the main structures in all alike. Furthermore, no geologist conceives the Eastern Australian plateaus as being raised to a uniform height. Such a structure would produce a series of towering precipices of uniform height at the place where the sea or the inland plains intersected them. As undulatory uplifts they reveal a gradual bending or warping in a general way from plateau summit to associated valley. Such plateau surface naturally may be interrupted by faults at places where the elasticity of the rock foundation has been exceeded.

Examples.—The Greater Sydney, Illawarra, and Blue Mountain areas consist of ordinary sandstone and shale beds, deposited in broad horizontal beds in Mesozoic time. The summit levels of the great plateaus, or upland valleys, of the Blue Mountains consist of these beds, which retain much of their original subhorizontal attitude, or slope of very small angular value, towards the east, the north-east and the north-west in different places. Along the front of the plateau escarpment, however, which marks the first great western rise of the plateau

from the associated coastal plains, these sandstone and shale beds possess the same general slope as that of the escarpment, namely, five to fifty-five degrees from the horizontal, according as the slope of the escarpment itself is slight or very pronounced.¹ Similarly, a compound undulatory swell may be noted in rocks of the above nature along the coastal area, with a depression extending along the Nepean drainage as far north as Richmond and Sackville Reach. Transverse warps, in part, tie the coastal undulations and uplands to the main plateau; nevertheless there is a distinct depression of longitudinal nature separating each. Thus the surface at Bulli Lookout slopes downward to Douglas Park and in a general westerly direction preparatory to rising again to the main plateau, and such topographical decline is matched by the structure, or dip, westerly of the sandstone and shale beds themselves. Similarly, the structural depression passes northerly beyond the great easterly bend of the Hawkesbury to the sea below Richmond and Windsor.

In the north-eastern portion of the State, a similar succession of sandstone and shale beds of Mesozoic age were deposited subhorizontally, and these are found dipping off the plateau sides in portions of the area drained by the south arm of the Clarence. (Farther north, on the Darling Downs area, the extension of this series conforms generally to the gentle slope of the plateau surface.) Nearer the coast a long high flat anticlinal structure of these beds occurs, and this is separated from the plateau spurs and foothills by a broken longitudinal valley. Great transverse arms of the plateau extend by undulating surfaces or as long leading spurs to the coast.

¹ Well seen by an examination of the mountain front from Kurrajong to Picton.

The great valley which, in Victoria, extends from a point west of Warrnambool to one north-easterly of Sale, by way of Camperdown, Geelong, Melbourne (Port Philip), Warragul, and Morwell, a distance of four hundred miles, approximately, is a grand example of a structural valley or depression separating two ranges (plateaus) or earth crests.

The Nandewar Range consists of Tertiary volcanics piled on an old surface of erosion, and is now an upland or plateau. The lower slopes of this plateau are practically dip slopes, in Permian, Mesozoic and Tertiary rocks to the Artesian Basin. The Nandewars themselves (volcanics in the main) form the main border at this place of the compound plateau of New England.

In other places, as in south-eastern Queensland, Sussmilch¹ has shown how the warped peneplain has been faulted markedly on the eastern or coastal side.

It is an inescapable inference, from a study of these typical and critical areas, that, inasmuch as the plateau or warped peneplain surface passes insensibly from the elevated erosion surface developed within the subhorizontal sandstone and shale series into that which has been developed within the folded sedimentary and igneous complex, the plateau margins in the folded complex are also dip and fault slopes in the main, but much modified by later erosion.

2. *Irregular longitudinal valleys within the plateau surface.*—The railway lines from Goulburn to Bombala (Southern Tableland), and from Walcha Road to Stanthorpe in New England and southern Queensland traverse the main plateaus of New South Wales in broad upland

¹ Sussmilch, C. A.: "The Geomorphology of the Moreton District, Queensland", *Proc. Roy. Soc. Queensland*, 1933, pp. 104-131.

valleys which are flanked by irregular and broken ranges, the highest of which occur nearer the margins of the plateaus. Some of these forms have been noted in the topographical descriptions above. The profiles of all these forms have been much modified by stream erosion. Examples of these and of subparallel longitudinal valleys in the inland and coastal foothills include the great valley mentioned above as extending from west of Warrnambool almost to the New South Wales border, and having a sympathetic trend with the Victorian coast; the lower plateau level subparallel to Mt. Hotham, Bogong, and other high points, and passing through Omeo; the Upper Hunter Valley; the irregular depression extending from Tamworth to Wialalda through Attunga, Barraba, and Bingara; the valleys drained by the main North and South Arms of the Clarence River; the depression drained by the Upper Richmond and continued south to the Clarence River; the main valley of the Orara; the Macquarie River valley in the Bathurst District; and so on. All these, on casual inspection, appear to be explicable on the assumption of differential stream erosion, but a study of the warped surface (peneplain) which constitutes the main plateau and a comparison with the forms exemplified in the extreme cases, such as the Alps, Himalaya, Andes, and other great cordillera, indicates the origin of these depressions as primarily structural (generally warping), and only secondarily erosional.

3. *Irregular bordering and cross ranges.*—The irregular and broken ranges which trend longitudinally with the plateau borders, together with the cross knots or transverse ridges which tie plateaus or bordering ridges together, have given rise to a considerable divergence of opinion as to their origin. Many of these broken ranges are arranged in somewhat side-stepping

manner; they are separated by broad upland-valleys which appear to be bounded entirely by rough ranges, but these valleys traced downstream may be observed, in many instances, to pass round the erstwhile bordering ranges by means of broad low gaps which open out, in turn, into similar broad valleys, the ranges being offset with respect to each other. Such valleys, at first sight, appear to be best explained as the result of long-continued erosion. In other places the broad valleys end against higher plateaus or ridges. In some districts the offsetting ranges may be seen to be transverse warps associated or not with faulting. The Guyra-Ben Lomond upland (4,300 to 5,000 feet in height) is an example; the Monaro Range, passing from the Gourock Range on the east through Nimmitabel (3,650 feet) to the Kiandra Plateaus (4,500 to 6,000 feet) is another. The origin of many bordering ranges, such as the Currockbilly Ranges, has not been explained satisfactorily as yet. In New England, however, certain bordering ranges such as the Nandewars, those also at the heads of the Bellinger, Macleay, Clarence, Hastings, Manning, and so on, appear to be higher undulations of the general elevated peneplains.

Certain other features occur, such as the various broken ranges of the coast which have been explained usually as residuals after differential erosion. Some of these are covered deeply with Tertiary drift and basalts,¹ the nature of this covering suggesting that they were deposited upon a horizontal or subhorizontal surface, and at a later stage have been warped to form the present broken longitudinal coastal ranges and transverse coastal spurs to the plateaus.

¹ Brown, Ida A.: "Some Tertiary Formations on the South Coast of New South Wales", *Proc. Roy. Soc. N.S.W.*, 1925, p. 387.

Conclusion.—In general, it may be stated that the study of the more exalted plateau examples in the various cordillera of the earth suggests that such structures are to be expected, either nascently, imperfectly, or well developed, in all plateau areas; and the great gaps or breaks which interrupt the longitudinal continuity of the plateaus appear to be structural depressions whose complements are the transverse ridges, ranges, or plateau knots.

SOME SIGNIFICANT FEATURES OF STREAM DRAINAGE.

General.—Among the features in the drainage of mountainous areas which have specially impressed geographers and geologists are:

(1) The valley-in-valley appearance of the main stream valleys themselves.

(2) The transection, or penetration, of massive ranges or lofty ridges by important streams in their passage from one intermontane valley to another. The nature of the penetration form is commonly a canyon, ravine, or other youthful form at the base passing vertically into valley-in-valley forms. Especially significant is this apparent attack by streams on their massive bordering walls in places where, very commonly, a relatively easy passage appeared open to the stream along broad open valleys in other directions.

These features are so common in mountainous regions generally that, in the present note, it would be impossible to enumerate all the important examples. A few illustrative and instructive examples, however, are selected as types from the Thibetan-Himalayan-Pamir region, the Andes, the North American cordillera, and from the highland or plateau region of Eastern Australia.

(i) *The Thibetan, Himalayan, Hindu Kush, Kuen Luen and Pamir areas.*—The persistency with which the great rivers of these areas pierce the mountain massifs opposed to them; the nature and profundity of the transecting canyons or ravines, and the apparent impossibility that the rivers themselves should traverse the opposed ranges directly and punch holes or ravines through and across them by their own impact, while easier courses, in many instances, seemed open to them in other directions, have been a source of perpetual astonishment to explorers and geographers alike.

The three main river systems of India are the Indus, the Ganges and the Brahmapootra, with their numerous important tributaries. The Indus-Sutlej system rises behind the great triple wall of the Himalayan system; flows through Thibet to the north of the trans-Himalaya; bursts through the massive rampart below Gartok; thence it occupies a long straight structural valley separating the compound trans-Himalaya from the lofty Ladakh Range; at some distance above Leh it leaves this intermontane valley and penetrates the Ladakh Range in a profound ravine; thence it flows north-westward until, near Gilgit and Nanga Parbat (26,500 feet) it turns south, transecting the Himalaya proper in a canyon reported to be the deepest known. The Shyok, a major tributary of the Indus, also reveals one of the finest stories possible of mighty mountain barriers breached by running water.

The Sutlej rises in the great structural valley separating the trans-Himalaya from the main snowy Himalaya, or Zaskar Range; thence it flows westerly, leaving the Lake Manasarowar Valley a little south of Gartok, and piercing the Ladakh Chain in a deep plateau valley; from this point it flows north-westerly along the

valley separating the Ladakh and Main Himalaya chains and enters the northern subparallel ranges of the latter at Totling. Here the main commercial "highway" of the district is compelled to leave the river, and to wind up and down the extensive valley-in-valley structures forming the vast plateaus or warped peneplain surface, while the Sutlej itself traverses the ranges in a wild ravine many thousands of feet below. Sven Hedin¹ describes these canyons very vividly. One pass in this passage by the "road" of the compound range or plateau country, was 16,000 feet above sea-level, while the roaring torrent of the Sutlej itself was only 10,000 feet above that datum (at the Lopchak Crossing). The Sutlej below this point pierces the Main Himalaya in still more profound gorges. Sven Hedin's photographs indicate that the Sutlej, in its passage through the great ranges, flows through great valley-in-valley forms.

The main tributaries of the Indus and the Sutlej reveal similar histories to those given above for the main streams, penetrating these loftiest ranges of the earth in almost impossible ravines.

The Brahmapootra takes its rise near the source of the Sutlej in a glaciated range lying in the structural depression separating the Trans-Himalaya and the Himalaya proper, and at a height approximating to 16,000 feet above sea-level. Thence, with more or less sluggish course, it flows along this persistent structural depression to Lhasa, falling from a height of 15,500 feet to 10,000 feet (Lhasa), in a distance probably exceeding 1,000 miles as measured along the river course. At a considerable distance downstream from Lhasa,

¹ Hedin, Sven: "Trans-Himalaya", 3 vols. See especially Vol. iii, 1913. Macmillan.

the great river transgresses the Main Himalaya in an impassable and profound ravine.

The Gangetic system, including not only the Ganges, but the main tributaries, such as the Jumna, Gogra, and Gumti, rise in the compound Himalayan ranges, and penetrate the opposed Himalaya and associated foothill ranges in great ravines as they pass southward to the Indian plains.

The streams of the Pamirs, the Hindu Kush, and of northern Thibet (including the Kuen Luen with the Altyn Tagh and Astin Tagh) tell a similar story. The Oxus heads partly in the lofty Nicholas Range separating the Great and Little Pamir, and partly (the Panja) in the mountain amphitheatre surrounding the Taghdumbash Pamir, and flows for many miles under the very edge of the towering Hindu Kush; thence it flows past Ishkashim northwards through "the narrow rock-bound valleys of Shignan and Roshan ere it sweeps north and west through the mountains and defiles of Darwaz". The buttresses and spurs of the Shignan Mountains are opposed almost at right angles to the trend of the Oxus, and (almost parallel with the general sweep of the Hindu Kush) overhang the Oxus channel like a mighty wall, and afford but little room for the maintenance of a practicable road. The Oxus, a little lower down, pierces the Darwaz Mountains almost normally to their strike.

The Karachukar with the Khunjerab, the Zarafshan or Raskam, as also the Yarkand, the Kara Kash, and other great streams of the northern Thibetan and Muztagh plateaus and ranges, pierce the opposed mighty barriers of the Karakoram, Kuen Lun, and associated lofty ranges, in their passage to the structural depressions of Eastern Turkestan.

(ii) *The Andes*, in the wider portions of South America, as stated above in the topographical descriptions, consist of wide and lofty plateaus bordered by great massive ranges, while, in the narrower portions of the continent, they consist of lofty parallel ranges separated by relatively narrow high and low intermontane valleys.

Along the whole course of the Andean chain, the main streams exhibit remarkable powers of breaching lofty ranges opposed to their flow. As an illustration, attention may be drawn to the fact that the Andes, for some distance to the north of Lat. 45° S., are divided by a well-defined longitudinal valley into two magnificent chains. The Palena River, with its two branches—the Pico and Carrenleufu—the Fetuleufu, the Puelo, and the Manso, cut across both chains, while the Renahue, Bodahue and Cochamo rise in the main eastern ridge, and breach the western chain. The Aiden and the Cisnes (Frias) also pierce the Andes where its main mass is a wide range.

These streams, then, as well as others less important in the same long belt, appear to burst through the Andean massif, or chains, in their passage (profound gorges) to the Pacific.

In the topographical description it was pointed out that the Peruvian Andes consist of high plateaus bordered east and west by lofty compound ranges running meridionally, and that the Central Ranges run sub-parallel to and between these high plateau barriers or margins. This Central Cordillera is the true water parting of the system. "No river except the Marañon (head stream of the Amazon) breaks through it either to the east or to the west, while more than twenty coast streams rise on its slopes and force their way through

the Maritime Cordilleras when it forces its way through the mountains at the famous Pongo de Mansericke and enters the Amazonian plains. The Huallaga rises north of Cerro Pasco and flows northward on the other side of the Central Cordillera for 300 miles. It breaks through the range at the Pongo de Chasuta, and falls into the Marañon. . . ."¹

Readers of Bowman's expeditions to Peru will recall his vivid description of the spectacular traverse, or piercing, of the Eastern Cordillera and "Front" Ranges of the Andes by the Urubamba, a tributary of the Ucayali.²

Among other remarkable streams of this nature in Peru and Bolivia may be mentioned the Santa River, which rises in Lake Conococha, 12,900 feet above sea-level, and is famous for its long course between the outer and central ranges of the Andes, in a structural trough known as the "Callejon de Huaylas", one hundred miles in length. Beyond this it breaks through the great western ranges in a profound ravine.

(iii). *North America* (Western Division).

In Canada, the Liard and Peace rise upon the Interior Plateaus and pierce the Rocky Mountains in their flow eastward to the Mackenzie. The Fraser also rises in the Rocky Mountains, flows for a great distance along the structural depression known as the Rocky Mountain Trench; turns abruptly round the northern end of the Cariboo Mountains; flows southwards through the Interior Plateau belt; and traverses the western ranges in its passage to the Pacific.

¹ *Encycl. Brit.*, Ed. xi. Art. "Peru".

² Bowman, Isaiah: "The Andes of Southern Peru", *Amer. Geogr. Soc.*, New York, 1916.

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The Columbia flows northwards along the Rocky Mountain Trench for a long distance; thence it turns abruptly round the Selkirk Range, and enters on a great southerly course into the United States by way of the Arrowhead Lakes. Passing into the Columbian Plateau Province "it receives the Spokane from the east and then turns sharply north-westward and describes a semi-circle with a diameter of one hundred miles around the Big Bend country. Turning again to the west on the Washington-Oregon boundary, it cleaves the Cascade Range from crest to sea-level. . . . On the flanks of the Cascade Range, the Columbia traverses the highest part of the plateau in Washington, altitudes on both sides of the river being more than 3,000 feet. A nearly straight course might be chosen from the mouth of the Spokane to that of the Snake without encountering any altitudes above 2,300 feet. It is plain, therefore, that the Columbia pays small heed to the general slopes of the plateau."¹

Fenneman points out, moreover, that "a more striking illustration of the same principle is found in the Snake River". This stream describes a great semicircle similar to the Big Bend of the Columbia, and, in doing so, elects, as it were, to pierce an opposing plateau about 7,000 feet in height, by means of a profound canyon 5,000 to 6,000 feet in depth.

The Yakima, one of the tributaries of the Columbia, is an exceptionally good example of a stream which transects ranges opposed to its course. "The Yakima crosses not only the transverse ridges but also the intervening troughs in a young valley. It cuts through the ridges in gorges from 1,000 to 3,000 feet deep, choosing

¹ Fenneman, N. M.: "Physiography of Western United States", 1931, p. 233.

its points of crossing without regard to sags in the crests which might, in several cases, have been found nearby.”¹

In the Wyoming basin the drainage is remarkable. The Green River meets the anticlinal uplift of the Uinta Range and traverses it in a 3,000 feet canyon. The Big Horn, Laramie, North Platte, Sweetwater, Bitter, Yampa, and other streams have similar histories,² although Fenneman calls attention to certain apparent differences in their histories as compared with those of the Columbian group.

Repeated stream revival is implied for the Canadian cordilleran drainage by Brock's statement that “throughout the whole region, including the eastern slope of the Rockies facing the plains . . . terraces are found. In some places thirteen or more well-marked terraces, rising one above the other, may be found.” They are common up to a height of 3,500 feet above the sea, and Brock has noted several at a height of 5,200 feet above sea-level.

The Appalachian Province.—The peculiarities of stream flow in the Appalachian Mountains, in traversing opposed ridges or plateaus, are too well known to be detailed. The main watershed of the area follows a very irregular course, crossing the mountainous area a little north of New River in Virginia. To the south of this point the streams head in the Blue Ridge; thence they traverse the opposed Unaka Mountains; cross the Great (Appalachian) Valley; thence they traverse the Cumberland Plateau in their journey to the Ohio and Mississippi Rivers. In the central Appalachian section, the rivers rise in, or beyond, the ridges diversifying the Great Valley; thence they flow through deep gorges, or water-

¹ Fenneman: *Op. cit.*, p. 266.

² Fenneman: *Op. cit.*, pp. 136-137.

gaps, to the Great Valley, and pass "by south-easterly courses across the Blue Ridge" to the sea.

(iv) *Eastern Australia*.—The points which impress most students of the geography of Eastern Australia are: the insignificant topographical appearance of the Great Divide; the wealth of valley-in-valley structures forming the uplands; and the apparent general indifference, in very many instances, of the main stream courses to the trend of the more massive topographic forms. In a very broad way it may be said that the coastal streams, for example, in their passage across and through the highlands, may be seen to flow in deep valleys (as much as four thousand feet and more in depth, in extreme cases) of the valley-in-valley type. Traced headward these canyons may be noted to be receding along the floors of mature valleys, which, in turn, are contained within much broader and more mature relatively-shallow valleys of the broad-upland type; these again appear to have been excavated within an earlier erosion (peneplain or subsummit) surface. This general statement necessarily needs many modifications to fit the description of the various specific drainage areas, because of the variable elevation of the individual plateau portions; the warpings, and faultings, the mineral composition, texture, grain, volume, and attitude, of the rock masses concerned; the local rainfall, temperature, weathering, and so on.

The Snowy River may be cited as a typical example of a coastal stream in Eastern Australia. This stream has a course of 300 miles approximately from its source in the high fault block of Kosciusko to the Gippsland Lakes in Victoria. It rises in a broad upland valley (warped peneplain surface) about 6,500 feet above sea-level, with

residuals of a bordering range rising to accordant levels (7,000 to 7,300 feet) and known as the Kosciusko or Main Range. The Snowy at its source traverses this upland valley, but passes downward by a series of rapids into a canyon about 2,000 feet deep within a distance of twenty miles. Its descent from the subsummit upland to the deep canyon is by means of a series of relatively-youthful valleys opening out into each other, the lower being embraced within the higher and outer forms, and the valleys descending to each other by means of rapids and gorges.¹ The rock structures within which these "valley-in-valley" forms occur are more or less homogeneous in that they occur in the main within a massive gneissic granitoid rock.

The Snowy leaves the Kosciusko block (itself tilted south-easterly) in a compound canyon whose profiles indicate a progressive elevation, with faulting and warping, at the margin of the tilted block. The stream then pursues a gentle course among the undulating ridges of the Jindabyne Valley (3,000 feet above sea-level) separating the rough Kosciusko and Varney Ranges. The Varney Range, which appears as a mere narrow ridge from Jindabyne and Berridale, is in reality a high plateau traversed for five miles by the Cooma-Kosciusko Road. Just below Jindabyne the Snowy forsakes its broad valley; turns sharply to the east and pierces the Varney Range (plateau) in a winding gorge, of the valley-in-valley type, as though the downward cutting action of the Snowy had been revived on several occasions. The bending of the stream to pierce the

¹ These features are better seen along the Snowy tributaries than along the main stream itself, because of the destructive action accomplished by the great volume of water carried down the main channel in flood-time.

Varney Range appears strange because of the apparently easy route open to the stream along the direction of the Mowamba valley. Thence to the east the river flows over the general level of the Monaro plateau for many miles, only to swing back on itself in a great arc, many miles in length, before resuming its general southerly course, when again it pierces high opposing ranges by means of wild and profound valleys and ravines.

The Nepean River, a few miles above Penrith, traverses the dense sandstone plateau although an easy way appears to have been open to it in the neighbouring structural depression underlain by the Wianamatta Shales. So also the same stream some miles farther downstream, and here known as the Hawkesbury, travels to the sea by means of a grand canyon which penetrates the dense sandstone plateau of the area, instead of seeking the sea by the obviously lower and easier route through the Parramatta-Sydney district.

The Clarence affords splendid examples of the transection of opposing ranges, as do also certain streams of the South Coast of New South Wales.

Sussmilch¹ describes excellent examples of the Brisbane River, and its tributaries, piercing high opposed ranges and ridges, when an obviously easier route lay close at hand.²

In passing, attention may be drawn to the highly significant report, with excellent aerial photographs, of

¹Sussmilch, C. A.: "Geomorphology of the Moreton District, Queensland", *Proc. Roy. Soc. Q'land*, 1933, pp. 104-131.

²For a totally different explanation of the topography of the Moreton District, see E. O. Marks, "Some Observations on the Physiography of the Brisbane River", *Proc. Roy. Soc. Q'land*, 1933, pp. 132-150.

Madigan,¹ dealing with stream drainage in Central Australia. "The rivers are of great antiquity and excellent examples of antecedent rivers. They follow the old southerly drainage direction, showing the paradox of cutting through the great 1,000-foot ridges at right angles, and ploughing their way across the anticlines."

Conclusions.

The study of these facts of drainage is most important in any serious discussion as to the origin of mountains. These valley-in-valley structures, these penetrations of mountain masses by mere streams, point to slow undulatory uplifts (accompanied or unaccompanied by faulting), punctuated by relatively-long inter-elevatory rests or pauses. Even if some of the "classic" examples of antecedent streams be demonstrated to be "super-imposed" streams, the facts of stream revival, and the slow saltations of undulatory elevation remain the same. The more rapid and more marked vertical movement of uplift in the later stages, is also noticeable, whereby profound canyons traverse broad mature valleys which are themselves cut in subsummit or summit peneplains.

ISOSTASY AND THE STRENGTH OF THE EARTH'S CRUST.

The student of isostasy naturally appreciates the fact that rock material possesses a certain amount of rigidity and strength² whose limit may not be overcome by gravitative stress, unless the mass of the rock material considered is actually very great. A cubic block of stone of one hundred feet edge, or a quartzite hill, one

¹ Madigan, C. T.: "The Physiography of the Western MacDonnell Ranges, Central Australia", *The Geog. Journal*, Vol. lxxviii, 1931, pp. 418-433.

² Rigidity is taken here as the opposite of flexibility, ductility, malleability, softness; while strength is taken as the opposite of frangibility.

thousand feet high, several miles in width and length and of the form of a flat dome may be considered as "eternally" enduring save for the action of weather and earth movements. An isolated mountain five or six miles in height and of exceedingly steep slope may be expected to sag under its own weight, although composed of the same dense and strong material as the "eternal" rock cube and hill mentioned above. In the rock cube and low quartzite hill strength and rigidity forbid the sensible expression of "rock flowage"; in the steep mountain of the same material gravitative stress overcomes the strength and rigidity of the rock structures. Unless the structures of the earth's crust be rigid to a degree, then mountain masses would overflow the neighbouring areas of lower elevation; and, moreover, the continental material would overflow the ocean floors. All irregularities in the earth's surface would be smoothed out thus. There actually is a definite tendency to overflow, as there is a tendency for all superficial structures to collapse, but the rigidity and strength of the materials of which they are composed (examples—the Pyramids of Cheops) enable them to retain their positions permanently, unless these materials stand high above their surroundings.

Isostasy—in common with all other activities tending to restore equilibrium in media—tends to express itself in the production of undulations,¹ which would tend to become more and more pronounced with the strength of the disturbing activity, and which, with the disappearance of the disturbing activity, would approximate more and more to the "level" or geoid form in proportion to

¹ In the case under consideration the undulations are emphasized at the earth's surface.

the lack of viscosity in the material affected. One extreme case would be a mixture of materials such as pitch, wax, paraffin, and so on, whereas another extreme would be found in variable materials of the rigidity and strength of steel, quartz, and massive siliceous plutonics. In the one case the earth's surface would approximate the form of the geoid; in the other it would have a marked permanent vertical relief.

An interesting comparison is suggested thus between the various modern mountain ranges and the influence of isostasy *versus* crustal rigidity *plus* strength. For example, is there, on the theory of isostasy, any fundamental qualitative difference between mountains of the present Appalachian and Cordilleran (Himalayan, Andean, Alpine) types, or do they rather express quantitative variations in vertical and horizontal movements by reason of the increase in rock flowage at the bases and sides of the grander (loftier) examples, and the approximation to rigid structures in the Cincinnati Arch, the Appalachian plateaus, the Canadian Shield, and so on? Bowie,¹ an eminent geodesist, considers that mountains are due to vertical uplift, despite the assertions concerning remarkable crustal shortenings, enormous horizontal overthrusts, and so on.²

In approaching the subject of the isostatic factor in modern mountain building, several facts of observation may be considered:

¹ Bowie, W.: "The Earth's Crust and Isostasy", *Geog. Review*, Vol. xii, 1922, p. 625; *ibid.*, "Geology from the Isostatic Viewpoint", *Scientific Monthly*, 1926, pp. 5-18.

² For a brief statement of recent views by Longwell, Putnam, Goranson, Lane, Chamberlin, see "Abstract of papers on Isostasy and related topics", *Jour. Wash. Acad. Sciences*, 1930, pp. 441-458.

(a) The earth is approximately an ellipsoid of rotation with an equatorial bulge. (It is a legitimate inference that a great change in the equatorial location would result in rapid bulging, by rock flowage, along the newer equatorial belt. In other words, the present equatorial bulge is maintained by the activities obtaining at the present time.)

(b) The earth's surface is an area of negligible downward pressure. This extremely important point appears, generally, to have been neglected in studies of mountain origins simply because such phenomenon is normal.

(c) The tendency of earth activities is to arrange the great land masses both meridionally and latitudinally; in other words, that these continental masses should be with their greater lengths north and south (*supra*, p. 258) and yet to oscillate towards each other within the tropical and subtropical (or lower latitude) belts. This is seen, on the one hand, in the apparent lag of certain continents to the east, and, on the other hand, in the existence of the unstable belts lying between North and South America, and within the Tethyan and East Indian areas.

(d) Despite the existence of the above-mentioned features, the surface of the earth appears to be, and to have been for ages, in a state of approximate isostatic equilibrium. (The inference is that disturbances within the earth's crust involved an enormous time factor in their operation.)

With these various points in mind, it may be advisable to consider several extreme cases in experimentation to illustrate the general principle.

(a) If an impulse be imparted to the surface of a great sheet of water by some agency, say, a storm wind, the

surface is thrown thereby into waves, the water appearing to travel forward, but (in deeper water areas) actually only rising up and down in long undulations, the movement of undulation itself passing onward. Along the shoreline, or plane of intersection of water and land, the water in the wave or undulation actually travels up the land slope. With the cessation of the wind (or earthquake shock or other disturbing activity), the waves still persist for a considerable period (as a ground swell), each being in a state of unstable equilibrium or balance with the others successively right along the whole width of the "fetch" affected by the storm wind.

(b) If a stone be dropped on to the surface of a still pond, it produces a depression which is compensated, or balanced, immediately, by a subcircular wave-crest. This wave travels outward, in ever-widening rings, not as one wave or undulation, but as a whole series of confocal and sympathetic waves, all unstable, nevertheless in equilibrium or balance, the mobility or unstability being proportioned to the fluidity or lack of viscosity in the water affected.

(c) The stripping of soil and "overburden" from the Yallourn lignite deposit in Victoria, and the dumping of same in long high lines—somewhat similar in shape to large long railway embankments—led to an undulatory disturbance in the same alluvial area, with the formation of long high ridges or undulations, with axes parallel to that of the dumped deposit. The reflected undulations were ornamented with strike faults and the pitch of the ridge or ridges also was undulatory. Here the loading of an area, which becomes swampy periodically, has produced a miniature mountain ridge

parallel with it, the two being in balance on either side of a depression or trough.

Similar effects may be observed in swampy ground traversed by railway embankments, the effect of a passing train being reflected in an undulatory joggle of rise and fall on a subparallel ridge resulting from the pressure of passing trains.

(*d*) If a solid mass of pitch be placed on an open pavement, and allowed to experience the influence of the diurnal variations of summer weather in a region where the shade temperature at times exceeds 90° F., the pitch may be noted to spread by a process of slow flowage which expresses itself as a series of subparallel or subconfocal undulations in arcuate form, the axes of the undulations travelling very slowly but being rendered temporarily stable during periods of cool or cold weather.

(*e*) A large rock, a granite seacliff, or even a thousand-foot hill composed of dense sandstone or igneous rock, may be supposed to resist indefinitely the tendency to spread by means of "rock flowage" under its own weight.

Imagine, however, a cube of rock, one hundred miles in height, to be placed gently on the earth's surface. Such cube would be noted to sink gradually into the crust of the earth, while around it, but at a considerable distance therefrom, and separated thence by deep depressions, the earth's upper crust—rocks and soil alike—would rise gradually in mighty ridges with intervening structural valleys.

The block itself meanwhile, although accommodating itself to its new bed by forcing the surface material outwards (with overthrusting, "rock-flowage", and so on), would not accomplish the sinking rapidly enough to prevent another activity coming into play. Thus the

rigidity of the block would be overcome at once and it would begin to crush itself under its own weight, and it would seek thus, as it were, to arrive more rapidly at a state of balance, or isostatic equilibrium, with its setting of the local rock crust. This would cause the block to spread definitely on itself near its base (zone of intersection with the zone of depressed crust adjoining). Hence would arise conflicting rock undulations needing readjustment, the undulatory spread of the vast rock cube crushing on its own base following up the outlying earth undulations resulting from the underthrust from the sinking block at the outset. A series of compound undulations or vast mountain ranges would result, all moving as unbroken undulations as opportunity offered, but actually, in many cases, breaking asunder and gliding subhorizontally in an outward direction for long distances owing to the lack of coherence established in the masses through the negligible amount of pressure, or support, existing at the earth's surface.

As the vast mass approached the condition of temporary stability, that is, the condition to which great mountain ranges approximate to-day when they appear as fixed and immovable to the untrained eye; when forests and ordinary life forms flourish upon their slopes, it may be noted that isostasy would tend to produce equilibrium in the original mass by the production of undulations within its surface, the central area being sunken as compared with the compound and marginal undulations of the block.

Coming now to the question of activities initiating mountain making, it may be noted that the studies of geologists, geographers, and geodesists, indicate the cause of the departure of the geoid from the figure of

the theoretical ellipsoid or spheroid of rotation as not to be sought in the doctrine of isostasy, but rather in the peculiar stresses which arise under certain conditions within a rotating earth "hanging upon nothing" and having also a surface of negligible pressure. Isostasy, however, does appear to indicate most definitely what form the larger irregularities of topography shall take, after due allowance has been made for lack of homogeneity of structure and composition of the earth, particularly the crust. This very important factor of form appears not to have received the attention it merits.

So soon as it is recognised that isostasy expresses merely the operation of an observed order of phenomena, in the establishment of a state of equilibrium in the earth's crust during, or subsequently to, a tendency to disturb equilibrium, then it is recognised also that its limits are set for very small areas and volumes by the offsetting action of rock rigidity and strength. Isostasy finds its maximum expression within areas of enormous extension and lofty topography. Isostasy tends to reduce to a minimum all deviations from the form of a body freely rotating (enormous magnitude implied). In the earlier stages following on disturbance, the definite tendency of isostasy is to produce wrinkles, undulations, or waves, in the unstable crust. Where the instability is greatest, the undulations are at a maximum in number, size and mobility; where the stability is most marked in the crust, the balancing of the related unstable areas will assume the form of broader and lower waves or undulations, the resultant effect being determined, in great measure, by the rigidity and strength already attained in that portion of the crust.

Geodesy indicates the efficiency of isostatic equilibrium at the present time, and geology indicates the slowness

of crustal movements. Taken together, these facts, in conjunction with what has been gone over before under the various main headings of this report, indicate that modern mountain making has been of the vertical, or slow-moving undulatory type; and that overthrustings and foldings may well be incidents in the formation of moving undulations, the time factor being enormously long. Now the form and arrangement of modern mountains indicates definitely that they have the general appearance of earth undulations, waves, or wrinkles. This is opposed to the popular method of explaining plateaus as results of sheer vertical uplifts, for, in such case, plateaus should be vast fault blocks bordered by sheer cliffs of comparable height.

Again the doctrine of isostasy is opposed to the idea that mountain masses are thrust outward rapidly by an activity acting sub-tangentially to the earth's surface. The undulations appear to arise as the reflection of pressure from the "zone of flowage" towards the area of negligible pressure (namely, the surface), expressing itself at this locus of maximum instability in the form of balanced undulations, which spread outwards, crushing their own alluvium (gravels); forming foothills in the process; and causing the more central portions to sag in minor wrinkles, with the production of bordering walls, arranged *en échelon* and with undulating pitch of crests.¹

¹ The topography, cited above, indicates that plateaus attain their maximum width and heights conjointly, in places either where they occur as buffers between two "stable" massifs, or (in a much lesser degree) where they occur opposite to extensive and stable nuclei. In such situations rigidity and strength tend, materially, to reduce the effect of isostasy in the production of a series of relatively narrow lofty undulations (ranges) and parallel intermontane valleys.

The facts of form in all mountainous, plain, and oceanic areas, supply convergent testimony. As such, all modern mountains, intermontane valleys, Great Plains, insular arcs, and oceanic "deeps" are considered, in this report, as early adjustments in a restoration to crustal equilibrium, moving *pari passu* with, or following on, disturbances in that crust. At the borders, or marginal areas, of old relatively-stable areas or nuclei, the undulations have been more crowded and pronounced in height, and have suffered actual translation of material, by analogy with ocean waves which have an actual movement up the shoreline.

Conclusions.—A study of isostasy, combined with actually recorded observations of the form and structure of mountains, suggests the similarity of structure for all, from a qualitative point of view, the more exalted types, such as the Himalaya, Kuen Luen, Hindu Kush, Bolivian and Peruvian Andes, and so on, being examples of crustal undulations which have been formed in relatively-unstable areas, and moreover, have been raised so high as to induce definite "rock flowage" near their bases, with the inevitable accompaniment of spreading, crushing of outwash and associated plain; and formation of subparallel and side-stepping foothills, in the process. On the other hand, low-lying plateaus in the ancient continental nuclei have been elevated so as to assume the form of low broad arches, generally with higher bordering ranges, revealing fracturings (faults), but the general elevation being so slight as not to afford opportunity for "rock flowage" to overcome the local rock rigidity and strength.

A necessity, in the proper study of isostasy, is the envisaging of the facts of form produced as a whole

and not in part only. Too much attention appears to have been bestowed on the geosyncline alone by stratigraphers and not enough on the inevitable geanticline alongside. Similarly, the students of mountain building emphasise the geanticline, but have not enough regard for the contemporaneous and associated geosyncline or trough. Isostatic activities produce earth undulations in their efforts to maintain unbroken the successive stages in approximations to stability of equilibrium. The rise of a geanticline implies the existence of an associated trough, geosyncline, or compound depression. The axes of each and all are unstable. Thus when the sediments of a loaded geosyncline are elevated in their turn (derived originally from the waste of related and unstable—or even migrant—geanticlines), a depression or geosyncline is formed to complete the newly-formed earth undulation or wave, the two balancing each other, and being also in balance or equilibrium with another associated elevation. When a mountain mass, such as the Andes or the North American cordillera, is formed, so does an associated forerunner become depressed to maintain the undulatory form as a balance. Hence, as the Pacific marginal ranges are formed, so do the recent lands or geanticlines alongside now become depressed below the sea, to form the compensating troughs. Hence comes the sinking of the old lands of Cascadia, Tasmanis, and so on.

GENERAL CONCLUSIONS.

Summarising the foregoing notes it would appear that:

(i) Mountain systems are arranged either marginally to continents themselves and to great continental nuclei,

or they occur as insular arcs related, generally, to the oceanic "deeps", and to the continental masses nearest to them.

(ii) Continents themselves (or continental nuclei) have relatively-depressed centres with raised margins broken over wide areas, through which the drainage of large inland plains discharges to the sea.

(iii) Oceans may be considered as basins the uniformity of whose floors is interrupted by compound earth undulations (island arcs and associated ocean "deeps"), the oceans themselves being bordered by high ranges or plateaus.

(iv) Modern mountains fall into two related groups: cordillera and ordinary plateaus, which have originated in the warping and differential elevation of low-lying surfaces of erosion, developed to varying stages of maturity or immaturity. The cordillera occur in relatively unstable, the lower plateaus in relatively stable, earth zones. In the cordilleran areas, the crust has been raised in large geanticlines or earth undulations which have been moulded in part against the more stable portions of the continental nuclei, and by reason of their great height have sagged in the centre and yielded outwards by rock flowage with the production of high plateaus, bordering ranges arranged *en échelon*, intermontane valleys, and side-stepping outer ranges or foothills. Overturning, overthrusting, and extensive crushing, of marginal sediments have ensued in this spreading action.

The lower plateau areas are wide and are characteristic of areas of relative rigidity and strength. The main points in which they differ from the cordillera are quantitative rather than qualitative.

(v) The age of modern mountain systems (as to their dominating profiles) appears to fall within one compound division of time, namely, closing and post-Tertiary.

(vi) The arrangement of streams and the nature of their containing valleys indicates that the formation of modern mountains is an exceedingly slow process, not uniform but saltatory, with long intervening pauses of relative "still-stand". The saltatory movements were exceedingly slow, allowing streams of large volume to maintain their positions against the opposing rise of of an earth undulation, or mountain range.

(vii) The earth's crust is, approximately, in a state of isostatic equilibrium.

It is a legitimate inference, therefore, that all modern mountains—namely, the great cordilleran systems, such as the Andes; the North American Cordillera; the European Alpine System; the Greater Asiatic Tethyan System; the Pacific insular arcs, such as the Japanese groups, the Philippines, the Netherland East Indies, New Guinea, New Zealand, and so on; together with the ordinary plateau systems such as the Appalachian Mountains, the Canadian Shield, the Brazilian Plateau and ranges, the Indian Ghats, the South African plateaus, and so on, are so many physiographic units, due to a great underlying control in late and post-Tertiary time within a rotating earth, with isostasy directing the forms which the crust of the earth takes during the process of restoration of crustal equilibrium. This restoration, in the earlier stages, partakes of the nature of tentative or unstable equilibrium, passing into more complete equilibrium, somewhat as storm waves pass gradually through stages of decreasing instability

of equilibrium into a calm sea. The storm waves are in balance with each other at any one instant of time even if the equilibrium attained thus is very unstable.

These remarks are applicable also to the mountains of Eastern Australia. They are plateaus, warped surfaces of erosion, with outlying foothills, blanketed, in places, with Tertiary alluvium, basalt, and weathering products; the plateaus viewed from below appear as a series of mountain ridges arranged in side-stepping manner, especially on the plateau marginal areas; they bear significant relations to the width of the associated continental shelf, to the location of the deep-sea margin, and to the general higher boundary of the great inland plains; they are upland valleys with marked development of valley-in-valley structures; and the antecedent nature of the main streams is pronounced.

It appears thus to be highly probable that the highlands of Eastern Australia form a physiographic unit, and are homologues of other great mountain systems, lacking ordinary cordilleran features because they have originated within areas of relative stability. By analogy with other great land blocks, the compensating or balancing feature of the Eastralian Highlands is to be sought on the one side in Western Australia across the inland plains (depression), and on the other in New Zealand and the related island chains across the depression of the Tasman Sea. The area comprising Australia, New Guinea, New Caledonia, New Zealand, together with the Arafura-Coral-Tasman depression, appears to be homologous with more compact areas such as North America, South America, Europe, Greater India, and China-Manchuria-Indo-China, with the East Asiatic insular arcs.

THE ESSENTIAL OILS OF *EUCALYPTUS*
MICRANTHA (DE CANDOLLE), INCLUDING
A FORM RICH IN PIPERITONE.

PART II.

By A. R. PENFOLD, F.A.C.I., F.C.S.,

Curator and Economic Chemist,

and F. R. MORRISON, A.A.C.I., F.C.S.,

Assistant Economic Chemist, Technological Museum, Sydney.

(With Plate II.)

(Read before the Royal Society of New South Wales, Nov. 1, 1933.)

In our Part I paper (JOUR. PROC. ROY. SOC. N.S.W., Vol. LXI (1927), pp. 267-278) reference was made to further investigations in progress on the essential oil of *Eucalyptus micrantha* obtained from various localities, including Brisbane, Queensland, which would be discussed in a subsequent publication. We are now in a position to make the results of this work available.

The most important result of the work is the potential value of *E. micrantha* which is so plentiful in the country adjacent to the north coast railway line running from Brisbane to Maryborough. The tree attains to considerable dimensions, as will be seen from an inspection of the photograph of trees growing at Sunnybank, near Brisbane, in contradistinction to the much smaller tree occurring in the coastal belt between Sydney and Brisbane (see Plate VI, *l.c.*). Trees of similar stature to those occurring at Sunnybank, Beerwah, and other parts of the north coast railway line, Queensland, can be seen in Glenbrook Park, Blue Mountains of New South Wales.

K—November 1, 1933.

Although the trees are morphologically inseparable, the essential oil of the leaves from the trees at Glenbrook differs considerably from leaves collected in Queensland. This mountain form will be dealt with in a subsequent publication.

Mr. C. T. White, F.L.S., Government Botanist of Queensland, has examined in the field trees occurring at both Brisbane and Glenbrook, New South Wales, and considers them to be identical. One of us (A.R.P.) has also examined the Queensland trees in conjunction with Mr. C. T. White, and can confirm his determination. This is, apparently, a further example of the occurrence of physiological forms in some of our well-known or comparatively common Eucalypts. This particular example is very similar to that described in our paper "The Occurrence of a Number of Varieties of Eucalyptus Dives as Determined by Chemical Analyses of the Essential Oils", Part I (JOUR. PROC. ROY. SOC. N.S.W., Vol. LXI, pp. 54-67). The essential oil of the trees from the mainland of Queensland differs so markedly from *E. micrantha* from Fraser Island, Queensland, and the New South Wales localities that it is considered desirable to distinguish this particular form or variety for commercial purposes by calling it *Eucalyptus micrantha*, Variety A. The essential oil contains 1- α -phellandrene 40%, and piperitone 40%-50%, as well as some piperitol. (The essential oil of the Type species consists principally of β -phellandrene, Δ^4 -carene, cineol and less than 5% of ketone.) It is, for all practical purposes, identical in chemical and physical characters with *E. dives* oil. With the exception of *E. citriodora* it is the only species of Eucalypt occurring in Queensland which has so far been observed which possesses economic value. It is worthy of commercial exploitation as a supplementary source

of piperitone in view of the probable scarcity of *E. dives* in the near future.

One of us (A.R.P.) had the pleasure of examining stands of this tree in company with both Mr. C. T. White, F.L.S., Government Botanist of Queensland, and Mr. C. J. Watson, of the Queensland Forest Service, in May, 1933, and was surprised at the wide distribution and excellence of the stands of this Eucalypt, which is the preponderating species in the coastal district between Brisbane and Maryborough. Unfortunately, the yield of oil is less than that obtained from *E. dives*, but at the same time this lower yield should not be an insurmountable difficulty in placing the oil on the market.

THE ESSENTIAL OILS.

The various collections of leaves and terminal branchlets made in both New South Wales and Queensland are set forth in the accompanying tables, Nos. 1 and 2. The chemical and physical characters provide an excellent separation of the Variety "A" (North Coast, Queensland) from the type material.

EUCALYPTUS MICRANTHA, TYPE.

Mr. C. T. White, F.L.S., Government Botanist, Queensland, in his private communications to the authors, has pointed out that *E. micrantha* is quite a common species between Brisbane and the New South Wales border, and, moreover, the trees seen by him near Tweed Heads, within a mile or two of the border fence, were rather stunted, due to the very poor nature of the ground in which they were growing.

Seeing that the material examined and described in our Part I paper was obtained within the County of Cumberland—November 1, 1933.

land, New South Wales, it was decided to examine the material occurring in the North Coast district of New South Wales. This would represent a locality approximately intermediate between Sydney and Brisbane. The results of the examination of the essential oil given in Table 1 agree very well with those described in the table on page 272 (*l.c.*). The chemical composition was found to be very similar, *viz.*, phellandrene, cineol (12%), sesquiterpenes, aromatic aldehydes and ketones, *etc.*

An observation of considerable interest was made with material collected by the Queensland Forest Service at Fraser Island, Queensland. This particular tree appears to be identical with the type species growing on the Hawkesbury Sandstone around Sydney. Fraser Island is a very remarkable place, the soil consisting principally of sand with considerable humus. The rainfall is very high, being about 60 inches per annum. The physical characters and chemical composition of the oils from the leaves and terminal branchlets were practically identical with those obtained from material collected in New South Wales. It is of particular interest to note that the principal terpene was found to be β -phellandrene, in contradistinction to Variety "A", which contains 1- α -phellandrene. The β -phellandrene appears to be generally associated with the ketone 1-4-isopropyl- Δ^2 -cyclohexen-1-one described in the *Journal of the Chemical Society*, London, 1931, pp. 1366-1369.

EXPERIMENTAL.

The oil obtained from the leaves from Fraser Island on 24th September, 1928, on account of its low content of piperitone, was subjected to examination with a view to observing any special differences in chemical composi-

TABLE 1.—*Eucalyptus micrantha* (De Candolle).

| Date. | Locality. | Weight of Leaves. | Yield of Oil. | d_{15}^{15} | a_D^{20} | n_D^{20} | Solubility in 80% Alcohol. | Ketones, Alde- hydes. | Cineol. | Phellan- drene. | Ester No. 1½ hr. Hot Sap. | Ester No. after Acet- yla- tion. | Remarks. |
|-----------|---|-------------------------|---------------------|---------------|------------|------------|----------------------------------|-----------------------------|---------|----------------------|---------------------------------------|---|---|
| | | lb. | % | | | | Vols. | % | % | | | | |
| 24/9/'28 | Fraser Island, Queensland | 62.5 | 2.0 | 0.8775 | -23.0° | 1.4869 | 10.0 | 7 | — | Abundance | 13.8 | 70.1 | Leaves supplied by Queensland Forest Service. |
| 18/11/'31 | P.T. Aubin, South Woodburn, New South Wales | 125.0 | 0.3 | 0.8852 | -9.0° | 1.4839 | 6.0 | 5 | 12 | Moderate quantity | 30.1 | 77.0 | Leaves in poor con- dition, due to "sweating" in transit, hence low yield of oil. |
| 18/12/'31 | P.T. Aubin, South Woodburn, New South Wales | 140.0 | 0.6 | 0.8842 | -11.1° | 1.4814 | 3.5 | 5 | 12 | Moderate quantity | 17.5 | 73.3 | |
| 8/8/'33 | Fraser Island, Queensland | 47.5 | 0.6 | 0.8745 | -20.7° | 1.4864 | 10.0 | Under 10 | — | Moderate quantity | 9.6 | 51.8 | Leaves supplied by Queensland Forest Service. |

tion. Three hundred cubic centimetres of crude oil were distilled at 10 mm. with the following results:

1st drops 58° at 10 mm.

| Fraction. | Volume. | d_{15}^{15} | a_D^{20} | n_D^{20} |
|---------------------------------|---------|---------------|------------|------------|
| 60°-65° | 152 cc. | 0·8520 | -25·0° | 1·4825 |
| 66°-70° | 46 cc. | 0·8694 | -24·25° | 1·4845 |
| 70°-80° | 28 cc. | 0·8553 | -24·85° | 1·4853 |
| 80° (10 mm.)-100° (6 mm.) | 25 cc. | 0·9388 | -36·15° | 1·4908 |
| 100° (6 mm.)-158° (5 mm.) | 38 cc. | 0·9695 | -1·0° | 1·5074 |

Determination of β -phellandrene.

Fractions Nos. 1, 2 and 3 were purified by redistillation over molten sodium at 60 mm. and finally at 20 mm.. The following fractions obtained from the 152 cc. fraction had the following chemical and physical characters, *viz.*:

| Fraction. | Volume. | d_{15}^{15} | a_D^{20} | n_D^{20} |
|-----------------|---------|---------------|------------|------------|
| 68°-70° | 77 cc. | 0·8505 | -25·0° | 1·4819 |
| 70°-72° | 25 cc. | 0·8513 | -26·0° | 1·4857 |

Both gave a good yield of nitrosite of melting point 98°, $[\alpha]_D^{20} +167\cdot4^\circ$.

Confirmation was obtained by oxidation of 25 cc. of the terpene fraction with cold 0·5% solution potassium permanganate. The small quantity of glycol isolated therefrom was treated with dilute sulphuric acid and steam distilled. A small quantity of oily distillate was obtained possessing the characteristic odour of the aromatic aldehydes. The semicarbazone prepared therefrom when recrystallised from methyl alcohol melted at 204°-205°.

The semicarbazone prepared from an authentic sample of phellandral isolated from the essential oil of *E. cneorifolia* melted at 204°-205°. A mixed melting point determination showed no depression.

Determination of Δ^4 -carene.

The chemical and physical characters of the principal terpene fractions pointed to the presence of another terpene accompanying the β -phellandrene. This is exemplified in the variation between the physical constants of the first and second fractions. Cymene could not be detected. A careful search revealed the presence of Δ^4 -carene.

Ten cubic centimetres of each fractions Nos. 2 and 3 were oxidised with alkaline potassium permanganate solution in accordance with the procedure previously described (JOUR. PROC. ROY. SOC. N.S.W., Vol. LXIV (1930), pp. 108-109). A small quantity of liquid acid was obtained which was converted to the semicarbazone. It melted at 180°-181°, and showed no depression of melting point when mixed with the semicarbazone of 1:1-dimethyl-2- γ -ketobutylcyclo-propane-3-carboxylic acid, an oxidation product of Δ^4 -carene.

Determination of Aromatic Aldehydes and Ketones.

Fraction No. 4, measuring 25 cc., was treated with 30% sodium bisulphite solution in accordance with the method described in *J.C.S.*, Vol. 121 (1922), p. 266. The quantity of aldehyde recovered from the solid bisulphite compound, 1.5 cc., oxidised before its physical characters could be taken. The acid was purified by solution in dilute sodium hydroxide, and after washing with ether the acid was liberated by the addition of dilute sulphuric acid. On recrystallisation from alcohol it melted at 144°-

145°, and was consequently identical with phellandric acid. Four cubic centimetres of ketone were regenerated by means of sodium hydroxide solution from the soluble bisulphite liquor. This substance possessed the following physical characters:

$$d_{15}^{15} 0.940 \quad a_D^{20} -53.6^\circ \quad n_D^{20} 1.4914.$$

The semicarbazone melted at 187°. It was, therefore, identical with the semicarbazone of 1-4-isopropyl- Δ^2 -cyclohexen-1-one. A mixed melting point determination with the semicarbazone of this substance from another source showed no depression.

Sesquiterpenes and Sesquiterpene Alcohols.

These constituents were concentrated in the last fraction, but owing to the relatively small quantity available their examination was not prosecuted further.

EUCALYPTUS MICRANTHA FROM N.S.W.

It was decided to make an examination of the sample of oil obtained from material collected at Coraki, New South Wales, in December, 1931. The oil very closely resembled that obtained from trees growing within the County of Cumberland as described in our Part I communication. One hundred cubic centimetres of crude oil were distilled at 10 mm. with the following results:

1st drops 60°.

| Fraction. | Volume. | d_{15}^{15} | a_D^{20} | n_D^{20} |
|----------------------------------|---------|---------------|------------|------------|
| 60°-65° | 60 cc. | 0.8707 | -8.5° | 1.4789 |
| 65°-85° | 22 cc. | 0.8767 | -9.7° | 1.4804 |
| 85°-128° | 12 cc. | 0.9335 | -18.1° | 1.4890 |

An examination of the various fractions which need not be described resulted in the identification and confirmation of cineol (12%), β -phellandrene, aromatic aldehydes and ketones, sesquiterpenes, *etc.*

EUCALYPTUS MICRANTHA, VAR. *A.*

In July, 1924, we were surprised to receive a sample of eucalyptus oil from the Australian Chemical Company of South Brisbane, Queensland, who reported that it had been distilled from the leaves and terminal branchlets of a Eucalypt which had been identified by the Queensland Government Botanist as *Eucalyptus micrantha*. This sample of oil, which was of a pale yellow colour, yielded the following chemical and physical characters on examination, *viz.*:

Specific gravity, $\frac{15}{4}$: 0.8919.
 Optical rotation: -62.2° .
 Refractive index, 20° C. 1.4811.
 Solubility in 80% alcohol: 0.7 volume.
 Cineol: Not detected.
 Phellandrene: About 40%.
 Piperitone: 43%.

The oil was, therefore, identical with that obtained from *E. dives*, which contains from 40%-45% piperitone. The composition was totally different from that published in our Part I paper for the essential oil of *Eucalyptus micrantha*. Enquiries made at the Queensland Forest Service revealed the fact that the tree from which the above-mentioned oil was obtained had a similar habitat to that of the New South Wales tree, *viz.*, poor coastal sandy soil.

Various collections of leaves and terminal branchlets were made from time to time by the Queensland Forest Service, and the results are given in Table 2. The material from Beerwah received on 1st April, 1927,

TABLE 2.—*Eucalyptus micrantha*, Variety "A."

| Date. | Locality. | Weight of Leaves. | Yield of Oil. | d ₁₅ ¹⁵ | a _D ²⁰ | n _D ²⁰ | Solubility in 70% Alcohol. | Piperi- tone Con- tent. | Phellan- drene. | Ester No. 1½ hour Hot Sap. | Remarks. |
|----------|--|-------------------------|---------------------|-------------------------------|------------------------------|------------------------------|----------------------------------|-------------------------------|--------------------|--|---|
| 2/7/25 | Sunnybank, near Brisbane | lb. 322* 174† | % 1·2 2·4 | 0·8949 | -51·0° | 1·4820 | Vols. 10·0 | % 41 | Abundance | 95·7 | |
| 1/4/27 | Beerwah, N.C. Line Queensland | 200* 80† | 0·6 1·3 | 0·8743 | -52·3° | 1·4823 | 4·5 | 24 | Abundance | 122·0 | Leaves received in unsatisfactory con- dition. Oil lost in transit of leaves. Air-dried leaves. |
| 13/10/31 | Tinana, near Mary- borough, Queens- land | 101 | 3·0 | 0·9011 | -48·2° | 1·4837 | 5·5 | 47 | Abundance | 87·5 | |
| 31/7/33 | Sunnybank, near Brisbane, Queens- land | 49·25 | 1·2 | 0·8970 | -57·0° | 1·4822 | 10·0 | 46 | Abundance | 15·6 | Fresh "sucker" leaves. |

* Green.

† Air-dried.

although included in the table principally on account of the locality from which it was obtained, was received in a decomposed condition; hence the low yield of oil and piperitone.

A perusal of the other average results shows that the yield of oil is about 1·2% to 1·5% on the fresh leaves and terminal branchlets. A thorough field investigation was made in Queensland during May, 1933, with a view to determining if any variation existed in the piperitone content of the oil from trees grown in different localities, but none could be detected. Over 750 lb. weight of fresh leaves and terminal branchlets were subjected to steam distillation. The oils were of a brownish-yellow colour with a typical peppermint odour characteristic of *E. dives*. The principal constituents which have so far been determined are 1- α -phellandrene about 40%, 1-piperitone, 40%-50% 1-piperitol, sesquiterpene, *etc.*

EXPERIMENTAL.

Each lot of oil obtained from the different consignments was separately examined. It is necessary for the purposes of this communication to record the results of the distillation and the examination of only one lot of essential oil, *viz.*:

Lot, 13/10/31, Tinana, Queensland.

300 cc. of crude oil distilled at 10 mm. gave the following results, *viz.*:

1st drops 50°.

| Fraction. | | | | | Volume. | d_{15}^{15} | a_D^{20} | n_D^{20} |
|-----------|----|----|----|----|---------|---------------|------------|------------|
| 50°-75° | .. | .. | .. | .. | 61 cc. | 0·8593 | -53·15° | 1·4979 |
| 76°-100° | .. | .. | .. | .. | 38 cc. | 0·8843 | -44·5° | 1·4835 |
| 100°-112° | .. | .. | .. | .. | 92 cc. | 0·9326 | -45·0° | 1·4854 |

Determination of l-a-phellandrene.

The first fraction boiling up to 75° at 10 mm. was re-distilled three times over molten sodium at 60 mm. and finally at 10 mm. when the final distillate of boiling point 58°-60° at 10 mm. measuring 46 cc. possessed the following constants, *viz.*:

$$d_{15}^{15^{\circ}} 0.8476, a_D^{20^{\circ}} -54.7^{\circ}, n_D^{20} 1.4790.$$

It gave a good yield of nitrosite of melting point 120°-121°. $[\alpha]_D^{20^{\circ}} +144.7^{\circ}$.

Cymene.

This hydrocarbon was not detected when the first and second terpene fractions were oxidized with 1% potassium permanganate solution.

Determination of Piperitone.

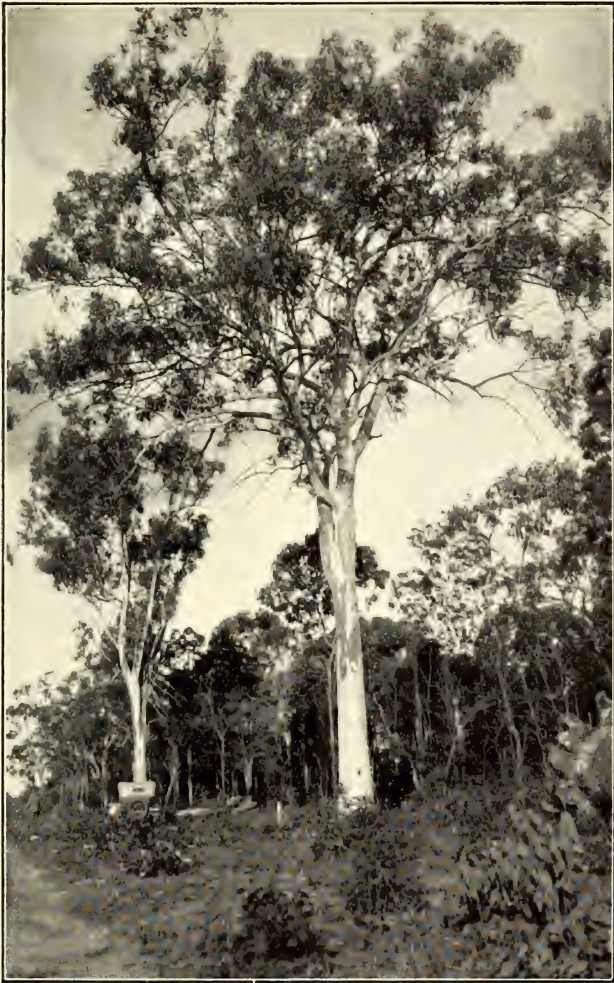
Fifty cubic centimetres of the third fraction boiling point 100°-112° at 10 mm. were treated with sodium sulphite solution at room temperature, when 38 cc. of ketone was regenerated by means of sodium hydroxide solution. The purified ketone of boiling point 106°-107° at 10 mm. possessed the following constants:

$$d_{15}^{15^{\circ}} 0.9374, a_D^{20^{\circ}} -4.8^{\circ}, n_D^{20} 1.4864.$$

The semicarbazone melted at 225°. The pinacone obtained by reduction with sodium amalgam melted at 163°-164°.

Determination of Piperitol.

The oil remaining after the treatment of the piperitone fraction with sodium sulphite solution was purified by washing with water and distillation under reduced



Trees of *Eucalyptus micrantha*, Variety A, growing
at Sunnybank, near Brisbane, Q.

pressure. The main fraction measuring 10 cc. possessed the following constants, *viz.*:

Boiling point 92° - 102° at 10 mm. $d_{15}^{15} 0.9235$, $a_D^{20} -22.6^{\circ}$,
 $n_D^{20} 1.4842$

It did not yield a derivative with naphthylisocyanate, indicating the absence of Δ^1 -terpinenol-4.

The chemical and physical characters, particularly the odour, pointed to the presence of piperitol. The identity of this alcohol was confirmed by oxidising it to piperitone with Beckman's chromic acid mixture. The piperitone thus obtained gave an excellent yield of semicarbazone (β form) of melting point 175° - 176° .

Our thanks are due to many friends who have interested themselves in this investigation, particularly to Mr. C. T. White, F.L.S., Government Botanist, Queensland, and the Queensland Forest Service, Brisbane.

We are grateful to Mr. P. T. Aubin, late of the Forestry Commission of New South Wales, for the collection and despatch of the leaves collected at Coraki, New South Wales, and to Mr. C. J. Watson, of the Queensland Forest Service, Brisbane, for personal collection of similar material from Sunnybank, near Brisbane.

THE MOISTURE EQUILIBRIUM OF TIMBER IN DIFFERENT PARTS OF NEW SOUTH WALES.

By M. B. WELCH, B.Sc., A.I.C.,
Technological Museum, Sydney.
(With One Text-figure.)

(Read before the Royal Society of New South Wales, Nov. 1, 1933.)

Although during the past four years a large amount of data has been collected in reference to the moisture equilibrium of timber in Sydney, and the results of a few experiments have been published, practically no information is available on the conditions which obtain in other parts of New South Wales. It is, of course, generally recognised that the moisture content is lower in the western districts than on the coast, but the degree is uncertain. In order to obtain more reliable data, approval was obtained in 1930 from the Director of Education for the co-operation of certain country high schools. On the advice of the Commonwealth Meteorological Bureau, the following stations were selected to give a fairly complete range of humidity conditions: Albury, Armidale, Bathurst, Broken Hill, Forbes, Goulburn, Hay, Murwillumbah, Narrabri, Tumut and Sydney.

Owing to limitations in the capacity of the balances available, comparatively small pieces of timber were used, measuring $6'' \times 3'' \times \frac{1}{2}''$. According to experiments conducted at Princes Risborough,¹ the moisture changes are

¹C. T. C. Stillwell: "The Moisture Content of Wood, with Special Reference to Furniture Manufacture", Bull. No. 5, Forest Products Research, 19.

practically independent of thickness in boards up to 1" in thickness, although naturally the thinner the board the quicker is the response to external changes of humidity. In order to ascertain the maximum variation in moisture content, all the samples were cut tangentially (backed off) and no end coatings were used. The surfaces were planed.

Ten timbers were selected, namely:

Three coniferous woods—

- (1) Queensland Kauri, *Agathis Palmerstoni*,
- (2) Hoop Pine, *Araucaria Cunninghamii*,
- (3) White Cypress Pine, *Callitris glauca*;

three hardwoods—

- (4) Tallow-wood, *Eucalyptus microcorys*,
- (5) Blackbutt, *E. pilularis*,
- (6) Spotted Gum, *E. maculata*; and

four cabinet timbers—

- (7) Queensland Maple, *Flindersia Brayleyana*,
- (8) Coachwood, *Ceratopetalum apetalum*,
- (9) Silky Oak, *Cardwellia sublimis*,
- (10) Pacific Maple, *Shorea* sp.

All the samples of one timber were cut from the same narrow board to avoid density variations.

The test pieces were despatched to the various schools in September, 1930, with instructions to place them in well ventilated rooms and freely exposed to the air on all sides. Nos. 1, 3, 5, 7 and 9 were to be in a room with a southerly aspect, and Nos. 2, 4, 6, 8 and 10 were given a northerly aspect. The samples were weighed to the nearest 0.1 g. at noon on each Tuesday during school term. Weighings commenced in October, 1930, and were continued until December, 1932. Whilst most of the schools kept excellent records and took a keen

interest in the work during 1930 and 1931, two schools, Bathurst and Murwillumbah, failed to return any records. Possibly owing to staff changes, some of the schools did not return records for 1932. Owing to school vacations, with one exception, no results were available for January.

At the end of the 1932 school period the test samples were recalled to Sydney, oven dried to constant weight and the percentages of moisture calculated. In order to condense the large number of available results as much as possible, the mean monthly figure was determined for each of the ten timbers and the mean of these was again taken. Therefore in the following table each figure is the mean of up to 50 moisture determinations.

TABLE I. *Mean Moisture Percentage of All Timbers for Each Month at Each Station.*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|-----------------|------|------|------|------|------|------|------|------|------|
| October, 1930 | | 13.3 | 13.6 | 10.5 | 12.8 | | 10.6 | 11.1 | 13.4 |
| November, 1930 | 11.7 | 12.4 | 13.2 | 8.3 | 9.7 | | 9.2 | 8.5 | 12.0 |
| December, 1930 | 12.0 | 11.9 | 13.2 | 8.4 | 10.3 | | 11.3 | 8.5 | 11.5 |
| January, 1931 | 11.7 | 11.4 | | | | | | | |
| February, 1931 | 12.0 | 11.0 | 12.9 | 6.6 | 8.0 | | 7.8 | 7.1 | 9.3 |
| March, 1931 | 12.3 | 11.1 | 12.9 | 9.0 | 10.3 | | 9.2 | 9.8 | 12.2 |
| April, 1931 | 12.3 | 11.1 | 14.0 | 9.7 | 11.6 | | 11.3 | 10.8 | 13.1 |
| May, 1931 | 12.4 | 12.3 | 13.9 | 10.7 | 13.9 | | 12.3 | 12.4 | 15.1 |
| June, 1931 | 12.4 | 13.6 | 13.6 | 12.2 | 14.9 | | 16.0 | 12.9 | 16.9 |
| July, 1931 | 13.0 | 13.8 | 13.0 | 13.2 | 15.2 | | 15.2 | 13.0 | 15.9 |
| August, 1931 | 12.2 | 13.6 | 12.6 | 11.7 | 14.8 | | 14.9 | 12.5 | 15.7 |
| September, 1931 | 11.6 | 13.0 | 12.4 | 9.3 | | | 13.5 | 10.5 | 14.8 |
| October, 1931 | 11.3 | 12.4 | 11.4 | 7.8 | | | 11.1 | 8.3 | 13.3 |
| November, 1931 | 12.1 | | 12.2 | 7.4 | | | 10.0 | 9.0 | 11.2 |
| December, 1931 | 11.8 | | 12.7 | | | | | | |
| January, 1932 | 12.0 | | | | | | | | |
| February, 1932 | 11.9 | | 11.0 | | 7.7 | 10.2 | | | |
| March, 1932 | 11.7 | | 11.2 | | 9.1 | 10.9 | | | 11.6 |
| April, 1932 | 11.7 | | 12.2 | | 11.1 | 12.3 | | | 12.7 |
| May, 1932 | 12.0 | | 12.5 | | 12.2 | 12.6 | | | 13.3 |
| June, 1932 | 11.8 | | 12.4 | | 13.2 | 13.6 | | | 15.6 |
| July, 1932 | 12.2 | | 12.5 | | 13.4 | 13.9 | | | 16.0 |
| August, 1932 | 11.8 | | 12.0 | | 12.5 | 13.4 | | | 15.3 |
| September, 1932 | 12.2 | | 12.6 | | 12.0 | | | | 13.9 |
| October, 1932 | 11.7 | | 12.1 | | 11.4 | 12.4 | | | 13.1 |
| November, 1932 | 11.6 | | 11.8 | | 9.6 | 11.0 | | | 11.2 |
| December, 1932 | 11.5 | | 11.1 | | 8.5 | 10.3 | | | 10.4 |

Station 1—Sydney.

„ 2—Albury.

„ 3—Armidale.

„ 4—Broken Hill.

„ 5—Forbes.

Station 6—Goulburn.

„ 7—Hay.

„ 8—Narrabri.

„ 9—Tumut.

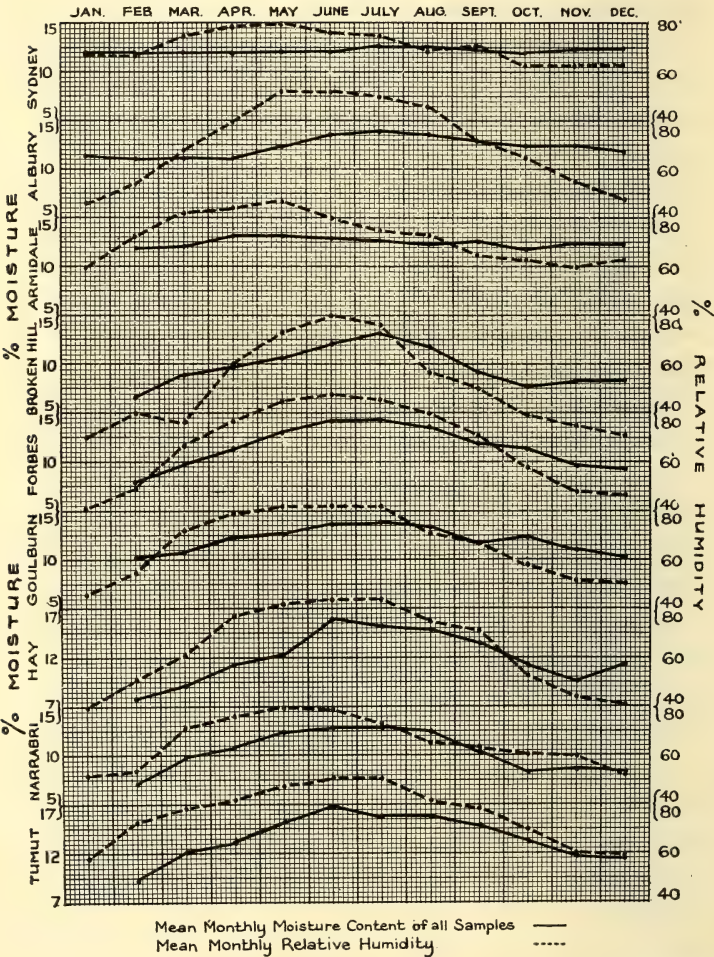
It should be recognised that these figures can only be taken as an indication of the moisture conditions in timber in dry, well ventilated positions, and that the amount of moisture varies if the humidity conditions are altered due to dampness or heating in the building. The results also are an average of the conditions found to occur at weekly intervals; naturally a more correct average would be obtained if daily weighings had been made.

Since the equilibrium moisture content of timber is a reflex of the atmospheric relative humidity, the schools were asked to record the wet and dry bulb temperatures daily. Unfortunately, some of the results were so obviously incorrect that it was thought advisable to obtain reliable data from the Commonwealth Meteorological Bureau, who kindly supplied the mean monthly relative humidities at 9 a.m., which are considered to give a fair indication of the daily average. The average relative humidities for the period October, 1930, to December, 1932, are shown in Figure I. Figures for Narrabri and Tumut were not available and therefore Warialda and Cootamundra were substituted, the Bureau considering that the conditions are similar.

In Figure I, also, the mean monthly moisture contents of the timbers have been averaged in order that the moisture percentages can be more easily compared with the mean relative humidities. An examination of the figures shows that there is comparatively little variation in the mean monthly moisture content for Sydney, a maximum of 13.0% occurring in July, 1931, and a minimum of 11.3% in October, 1931, although in July, 1932, the mean was 12.2%, only 0.2% above the summer figures for December, 1930, January, 1932, and February, 1931. The mean monthly relative humidity reached a maximum

of 84% in May, 1932, and a minimum of 60% in October, 1931. At Albury, a maximum average monthly moisture percentage of 13.8 was found in July, 1931, and a

FIGURE I.



minimum of 11.0 in February, 1931; the maximum monthly relative humidity was 92% in May, 1931, and the minimum 43% in December, 1931. Taking into

account the extreme humidity range, one would have expected a greater variation in the moisture content of the wood.

Armidale showed a maximum moisture average of 14.0% in April, 1931, and a minimum of 11.0% in February, 1932. Although there was a decided winter increase in 1931, this was much less pronounced in 1932. The maximum monthly relative humidity was, however, 88% in July, 1932, and the minimum 51% in October, 1931, although it averaged 86% for March, April and May, 1931. The maximum moisture content at Broken Hill was 13.2% in July, 1931, and the minimum 6.6% in February, 1931. This very marked winter increase is clearly reflected in the corresponding increase in the winter relative humidity. The monthly relative humidity reached a minimum of only 29% in February and December, 1931, and a maximum of 81% in June, 1931. In January, 1932, the relative humidity was only 25%, and if weighings had been made during this period it is possible that the moisture content of the wood might have fallen even below 6.6%. Forbes also showed a decided winter increase, the moisture varying from 7.7% in February, 1932, to 15.2% in July, 1931; the humidity varied from 39% in January, 1932, to 88% in July, 1931, and 89% in June, 1932. At Hay the conditions experienced were somewhat similar, the moisture varying from 7.8% in February, 1931, to 16.0% in June, 1931, whilst the humidity varied from 44% in November, 1930, 45% in January, 1931, and 39% in December, 1931, to 86% in June, 1931; in January, 1932, the humidity was only 34%, but no weighings were made. At Narrabri the winter increase was somewhat less pronounced, the maximum being 13.0% in July, 1931, and the minimum 7.1% in February, 1931; at Warialda the humidity varied

from 52% in January, 1931, to 82% in June, 1931. Tumut also showed a definite winter increase in moisture, ranging from 9.3% in February, 1931, to 16.9% in June, 1931; the humidity at Cootamundra was 49% in January, 1931, 90% in June, 1931, 91% in July, 1931, and 92% in July, 1932.

An examination of Figure I shows very clearly that whereas Sydney is particularly fortunate in possessing such remarkably equable relative humidity conditions (although of course occasionally days are experienced when the humidity falls to 40% and even lower), many country centres experience pronounced variation between winter and summer conditions. The remarkably low monthly average of only 25% r.h. at Broken Hill at 9 a.m. can only mean that even drier conditions must have been experienced on individual days with a consequently increased desiccation of timber exposed to such conditions. High atmospheric temperatures are also common in the summer, the maximum reached during the experiment being 116° F. at Hay, 114° at Broken Hill, 112° at Forbes, 110° at Albury and Wialalda, 106° at Sydney and Goulburn, 99° at Armidale, 98° at Cootamundra.

The maximum and minimum percentages of moisture recorded for individual timbers are shown in Table II. It is obvious that there is considerable degree of apparent variation between the maximum and minimum for the various species, but again the fact must not be lost sight of that these weighings are isolated points on a continuously varying curve, and that a dense timber which is slower in taking up or losing moisture may be lagging behind a lighter timber, and thus show a lesser variation than it might ultimately attain. It is of course equally possible for the lagging timber to show a greater varia-

tion than one which responds quickly to atmospheric changes.

Queensland Maple showed the greatest variation, namely, 10·6%, and at seven out of the nine stations gave the greatest alteration in comparison with the other timbers. At two stations Coachwood showed the greatest variation. Silky Oak showed a maximum variation of 9·7%, Queensland Kauri 9·4%, Hoop Pine 9·3%, Coachwood 8·6%, Blackbutt 8·2%, Cypress Pine 7·4%, Tallow-wood 7·2%, Pacific Maple 7·1%, and Spotted Gum 6·8%. The mean variation of each timber at all stations was greatest in Queensland Maple with 5·9%, followed by Silky Oak 5·2%, Queensland Kauri, Hoop Pine and Coachwood 5·1%, Blackbutt 4·7%, Pacific Maple 4·4%, Cypress Pine 4·3%, Tallow-wood 4·1%, and Spotted Gum 4·0%. These timbers were, however, not all in the same positions at each station, and the results may not therefore be strictly comparable.

The difficulty in arriving at a suitable moisture content for seasoned timber in many inland districts is very apparent. Thus, whereas Tallow-wood showed only a 1·0% variation in Sydney, at several country stations the variation was over 7·0%. Similarly Blackbutt showed 2·0% variation in Sydney and over 8% elsewhere, Hoop Pine 1·2% and over 9%, Cypress Pine 1·6% and over 7%, Silky Oak 3·1% and over 9%, Kauri 2·7% and over 9%, Coachwood 1·2% and over 8%, Spotted Gum 1·0% and over 6%, Pacific Maple 1·6% and over 7% and Queensland Maple 3·3% and over 10%. The only approximation which appears possible is to use the mean of the maximum and minimum figures as an average moisture content. The figures also demonstrate the necessity for all woodwork to be protected as far as possible with moisture resistant coatings in areas where there

is a considerable variation between winter and summer conditions. It is obvious, for example, that furniture should be coated both inside and outside in order to slow down the gain or loss of moisture as much as possible.

Comparing the mean moisture percentages $\left(\frac{\text{max.} + \text{min.}}{2}\right)$ of each timber for all stations, it is found that Queensland Maple showed a maximum of 12·9% and Hoop Pine a minimum of 10·7%, Tallow-wood 12·0%, Queensland Kauri, Cypress Pine, Blackbutt and Pacific Maple 11·8%, Coachwood 11·6%, Spotted Gum 11·5% and Silky Oak 11·1%. This individual variation in the equilibrium moisture content of timber exposed to identical conditions is a characteristic which is difficult to explain.

Although it might have been expected that timber placed in a room with a northerly aspect would show a greater variation than that placed with a southerly aspect, owing to greater temperature variations and hence greater relative humidity variation, such did not always prove to be the case. The mean of the maximum variations for the five timbers placed with southerly and northerly aspect at Sydney was 2·6% and 1·2% respectively, Albury 3·3% and 3·0%, Armidale 3·1% and 3·3%, Broken Hill 6·7% and 6·4%, Forbes 7·4% and 7·7%, Goulburn 3·7% and 3·7%, Hay 8·7% and 7·3%, Narrabri 7·1% and 5·1%, and Tumut 7·7% and 7·5%. Thus at six stations the variation was greater with a southerly aspect, at two stations the northerly aspect showed the greater variation and at one station the results were the same. The mean variation of all stations was, southerly aspect 5·6%, northerly aspect 5·0%. Although a more accurate comparison could have been obtained by using duplicate samples in either position, this was not considered advisable owing to the extra

work involved in weighing. The samples were therefore arranged so that they were paired as nearly as possible in their general properties, although it was realized that the same woods may vary in their response to atmospheric changes.

In conclusion, acknowledgment is freely given to those science masters in the various high schools without whose help the experiment would have been impossible, and to Mr. F. B. Shambler, who prepared the samples and who assisted throughout the work.

SUMMARY.

In order to obtain information relative to the equilibrium moisture content of woods in various parts of New South Wales, small samples of ten different timbers were despatched to ten country towns. With certain exceptions these, together with a similar set of timbers in Sydney, were weighed weekly from October, 1930, to December, 1932, and the moisture contents calculated.

Whereas in Sydney the mean monthly moisture content showed a variation of less than 2% during the period with practically no difference between winter and summer conditions, in most country centres there was a very pronounced increase in moisture during the winter, amounting to as much as 7.4%.

The greatest maximum variation in the moisture content of any timber was 10.6% in Queensland Maple, and the least maximum variation of 6.8% occurred in Spotted Gum, whilst the mean maximum variation was highest at 5.9% in Queensland Maple and the lowest in Spotted Gum, 4.0%.

Queensland Maple showed the highest mean moisture content of 12·9% for all stations, and Hoop Pine the lowest, 10·7%.

In general, timber exposed in a room with a southerly aspect showed a greater variation in moisture content than that exposed to a northerly aspect.

The results of the experiment clearly indicate the necessity for thoroughly protecting woodwork to be used in inland districts with moisture resistant coatings in order to minimise as far as possible the excessive normal variation between winter and summer conditions.

THE ESSENTIAL OILS OF THE GENUS
CALYTHRIX.

PART I.

CALYTHRIX VIRGATA.

By A. R. PENFOLD,* F.A.C.I., F.C.S.,

Curator and Economic Chemist,

and F. R. MORRISON,* A.A.C.I., F.C.S.,

Assistant Economic Chemist, Technological Museum, Sydney.

(With Plate III.)

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

The botanical features of this Myrtaceous shrub are described in *Curtis Botanical Magazine*, Vol. VIII, 1834, p. 3323. The plant was originally discovered by Allan Cunningham in the hilly country around Bathurst, and introduced by him in 1823 to Kew Gardens. The species appears to have been placed with numerous others by later botanists, such as Bentham, Mueller, *etc.*, under *Calythrix tetragona*. This resulted in *Calythrix tetragona* becoming a very variable species. The confusion of botanical nomenclature has prevented our work on the essential oils of various species of *Calythrix*, collected in other States as well as in New South Wales, commenced about 1920, from being summarised and published. It is due to the efforts of Mr. E. Cheel, Botanist and

* Our thanks are due to our botanical colleagues, Messrs. E. Cheel, Botanist and Curator of the National Herbarium, Sydney, and M. B. Welch, B.Sc., Economic Botanist, Technological Museum, for their assistance in these botanico-chemical investigations.

Curator of the National Herbarium, Botanic Gardens, Sydney, who undertook a revision of the Genus, that the botanical tangle has been unravelled and our work rendered available for publication.

Calythrix virgata is a shrub about 3' to 5' in height, with very small dark green leaves and characterised by the profuse and very beautiful flowers, either white or pink, and the calyx lobes which are lengthened into fine hair-like awns. The best specimens of the shrub have been observed in the Megalong and Burragorang Valleys of New South Wales, especially the former, where it occurs in considerable quantity.

The Essential Oil.

We are indebted to Dr. Francis Lions, Department of Organic Chemistry, University of Sydney, for bringing the essential oil of this shrub under our notice. Hearing that we were engaged in an investigation of the essential oils from the Genus *Calythrix*, he very generously presented to us in 1928 a sample of oil distilled by himself when travelling through the Megalong Valley, New South Wales, in January, 1927. He also directed our attention to its occurrence in the Lower Burragorang Valley (5 miles above the junction of the Cox and Wollondilly Rivers), a location which we visited in June, 1932.

Dr. Lions' sample of oil was used for a preliminary investigation. It was subsequently decided to secure consignments of leaves and terminal branchlets, and altogether a total of 600 lb. weight was subjected to distillation with steam.

The oils varied from pale yellow to a deep golden brown in colour, usually the latter, and were obtained in an average yield of 0.5%. The oils possessed very pleasant fragrant odours, characteristic of the esters of

citronellol and geraniol. In one instance, notably in connection with the Burragorang sample, the odour of pinene somewhat adversely affected the aroma, which was found to be at its best when the plant was distilled in full flower.

The principal constituents that have so far been identified were found to be d- α -pinene, citronellol and geraniol, both free and combined as acetic, formic, citronellic and dehydrocitronellic acid esters. Linalool appeared to be present in small quantity, but although it was sought and specially tested for over a period of years, its presence could not be confirmed.

The determination of citronellic and dehydrocitronellic acids is of special interest. The occurrence of oily acids with an odour of capric acid in relatively small quantity is not uncommon in many Australian essential oils. These acids have usually been determined by the amount of silver left on ignition of the silver salts. The silver salts of both capric and citronellic acids yield approximately the same amount of silver on ignition. We are of the opinion that the occurrence of capric acid in a number of our previous papers, particularly where citronellal or citronellol has been found in quantity, has been reported in mistake for citronellic and dehydrocitronellic acids.¹ Citronellic acid and a dehydrocitronellic acid have been obtained in quantity from the essential oil of another species of *Calythrix*, and, consequently, their occurrence and properties will be described more fully in a later publication.

¹ See JOUR. PROC. ROY. SOC. N.S.W., Vol. LIX (1925), p. 38, "The Essential Oil of *Boronia citriodora*, and the Occurrence of Citronellol"; and Vol. LXV (1931), p. 91, "The Essential Oil of *Leptospermum Liversidgei*, Variety B, and the Occurrence of Isopulegol, Part I".

EXPERIMENTAL.

A total of 600 lb. weight of the leaves and terminal branchlets, cut as for commercial purposes, yielded, on distillation with steam, crude oils possessing the chemical and physical characters shown in Table 1. The essential oils from all consignments were individually examined, but for the purpose of this paper only the results from the admixture of two lots obtained from leaves collected at Megalong Valley will be described:

250 cc. crude oil were washed with 8% sodium hydroxide solution for the removal of free acids and phenolic bodies. The oil was then saponified with alcoholic potassium hydroxide solution at room temperature.

228 cc. were returned and subjected to distillation at 10 mm., with the following results:

| Fraction. | Boiling Point. | Volume. | $d_{15}^{15^\circ}$ | $a_D^{20^\circ}$ | $n_D^{20^\circ}$ |
|-----------|----------------------|-----------|---------------------|------------------|------------------|
| 1 | 55°-60° | cc. 45 | 0.8627 | +38.5° | 1.4672 |
| 2 | 61°-96° | 4 | 0.8707 | +19.0° | 1.4663 |
| 3 | 97°-109° | 70 | 0.8759 | +3.0° | 1.4686 |
| 4 | 109°-111° | 62 | 0.8776 | +3.5° | 1.4707 |
| 5 | 105°-115° (5 mm.) | 8 | 0.9049 | +4.0° | 1.4795 |
| 6 | 116°-135° (5 mm.) | 16 | 0.9392 | +2.0° | 1.4932 |

For purposes of comparison the distillation results of 100 cc. of crude oil (lot 21.10.31) before saponification are given, *viz.*:

1st drops 45° (10 mm.).

| Boiling Point. | Volume. | $d_{15}^{15^\circ}$ | $a_D^{20^\circ}$ | $n_D^{20^\circ}$ | Ester No. |
|----------------|---------|---------------------|------------------|------------------|-----------|
| | cc. | | | | |
| Below 60° .. | 14 | 0.8629 | +38.45° | 1.4658 | 3.7 |
| 61°-105° .. | 11 | 0.8663 | +27.8° | 1.4647 | 17.7 |
| 106°-121° .. | 62 | 0.8927 | +3.6° | 1.4660 | 103.6 |
| Residue .. | 11 | 0.9491 | Too dark | 1.0905 | 99.6 |

TABLE 1.—Essential Oils of *Calythrix virgata*.

| Date. | Locality. | Weight of Leaves. | Yield of Oil. | d_{15}^{15} | 20° a_D | 20° n_D | Solubility in 70% Alcohol. (By Weight.) | Ester No. $1\frac{1}{2}$ hr. Hot Sap. | Ester No. After Acetyla- tion. | Remarks. |
|-----------|--|-------------------------|---------------------|---------------|-----------------------|-----------------------|---|---|--|---|
| 25/6/'28 | Megalong Valley, N.S.W. | lb. — | % — | 0.8823 | +12.75° | 1.4637 | Vols. 1.3 | 53.8 | 192.3 | Sample of oil presented by Dr. Lions, Sydney University. Distilled by himself, January, 1927. |
| 9/9/'29 | Kirby's Farm, Megalong Valley, N.S.W. | 190 | 0.43 | 0.8833 | +14.3° | 1.4671 | 3.3 | 53.9 | 182.3 | Oil possessed very frag- rant odour of Citron- ellol and Geraniol. |
| 21/10/'31 | Kirby's Farm, Megalong Valley, N.S.W. | 237 | 0.47 | 0.8913 | +11.8° | 1.4684 | 1.8 | 90.3 | 180.8 | Plant in full flower. Most fragrant odour of any sample, due to high ester content. |
| 28/6/'32 | Cox River, Burragorang Valley, N.S.W. | 61.5 | 0.3 | 0.8923 | +12.0° | 1.4751 | Insoluble 10.0 | 31.7 | 164.2 | Inferior odour due to low ester content. |
| 14/9/'33 | Kirby's Farm, Megalong Valley, N.S.W. | 112 | 0.36 | 0.8855 | +13.2° | 1.4677 | 1.3 | 52.5 | 181.2 | Time of year respons- ible. |

Determination of Alkali Soluble Constituents.

The various consignments of oil after washing with 5% to 8% sodium hydroxide solutions yielded from 0.4% to 0.5% of a mixture of acidic and phenolic substances which were not identified.

Determination of d- α -pinene.

The fractions distilling below 60° at 10 mm. were individually examined by repeated redistillation over metallic sodium. Fraction No. 1 on similar treatment yielded the following distillate:

Boiling point 155-156° (764 mm.) $d_{15}^{15^\circ}$ 0.8629, $a_D^{20^\circ}$ +39.9°, $n_D^{20^\circ}$ 1.4658.

Oxidation with potassium permanganate resulted in an excellent yield of pinonic acid of melting point 70° and $[\alpha]_D^{20^\circ}$ +97.8°.

The semicarbazone of the pinonic acid melted at 207°.

Determination of Free and Combined Alcohols.

Fractions Nos. 3 and 4 were treated separately by admixture with equal weights of phthalic anhydride and benzene and heated on a boiling water bath for two hours. The regenerated alcohols from each fraction were mixed together and subjected to fractional distillation at 10 mm. with the following results, viz.:

| Boiling Point. | Volume. | $d_{15}^{15^\circ}$ | $a_D^{20^\circ}$ | $n_D^{20^\circ}$ |
|----------------|---------|---------------------|------------------|------------------|
| 110°-111° | cc. 34 | 0.8658 | +2.8° | 1.4616 |
| 111°-112° | 26 | 0.8649 | +3.0° | 1.4611 |
| 112°-114° | 7 | 0.8712 | +2.4° | 1.4630 |

All these fractions possessed an excellent rose odour characteristic of a mixture of citronellol and geraniol. The variation in boiling point and physical characters indicated such an admixture. The silver salts of the phthalic acid ester of each fraction were prepared, and these on recrystallisation with methyl alcohol melted as follows:

(1) 124-125°, (2) 125°, (3) 127°.

The melting point of the silver salt of the phthalic acid ester of citronellol is 126°. Geraniol was tested for by heating one gram lots of the various fractions with 1.5 grams diphenylcarbamine chloride and 1.35 grams pyridine for 2 hours on a water bath. The purified diphenylurethane melted at 69-70°. On repeated recrystallisation the melting point was raised to 82°. The melting point of the diphenylurethane of geraniol is 82.2°.

Free alcohols were tested for in the crude oils by treatment with phthalic anhydride in benzene solution. The resulting product, after two hours' contact was shaken with a given quantity of decinormal potassium hydroxide solution and titrated with decinormal acid solution. The free alcoholic content calculated as geraniol varied from 22% to 25%. The free alcohols isolated by means of phthalic anhydride possessed the following constants:

Boiling point 110°-115° (10 mm.) d_{15}^{15} 0.8700, a_D^{20} +3.4°, n_D^{20} 1.4610.

The silver salt of the phthalic acid ester was prepared in the usual way and melted at 126-126.5°. The diphenylurethane of geraniol was also prepared from the same sample and melted at 82°. The free and combined

alcohols were, therefore, found to consist of citronellol (80% by formylation) and geraniol.

Presence of Linalool?

In the examination of the residual oil left after the removal of the citronellol and geraniol by treatment with phthalic anhydride there was always obtained a small fraction with a characteristic odour of linalool. Two such fractions from different lots of oil had the following constants, *viz.*:

1. Boiling point 80°-90° (10 mm.) $d_{15}^{15^{\circ}}$ 0.8829, $a_D^{20^{\circ}}$ +1.6°, $n_D^{20^{\circ}}$ 1.4658.

2. Boiling point 80°-90° (10 mm.) $d_{15}^{15^{\circ}}$ 0.8817, $a_D^{20^{\circ}}$ +6.8°, $n_D^{20^{\circ}}$ 1.4665.

Attempts to prepare derivatives with both phenylisocyanate and naphthylisocyanate were unsuccessful.

Determination of the Esters.

The alkaline liquors resulting from the saponification of the crude oil with alcoholic potassium hydroxide solution at room temperature were washed with ether to remove traces of dissolved oil and evaporated to a small bulk. The concentrated liquors were acidified with dilute sulphuric acid and subjected to steam distillation. The small quantity of oily acid floating on the surface of the distillate was separated and examined. It had an odour of capric acid and $d_{15}^{15^{\circ}}$ 0.9401 $a_D^{20^{\circ}}$ +3.4° $n_D^{20^{\circ}}$ 1.4629. The amide prepared through the acid chloride and purified from low boiling petroleum ether (45°-50°) melted at 89°-90°. 0.1822 gram of the silver salt of the acid gave on ignition 0.0702 gram of silver = 38.5% Ag. About 0.5 gram of the acid was obtained from 100 cc. of the crude oil.

This liquid acid, which appeared to be a mixture of citronellic and dehydrocitronellic acid, will be fully discussed in a subsequent paper.

The aqueous distillate was neutralised with ammonium hydroxide solution and evaporated to a small bulk. The silver salts were prepared from various fractions and crystallised from boiling water. The earliest fractions could not be handled owing to rapid reduction to metallic silver; an indication of the presence of formic acid. Both formic and acetic acids were detected by qualitative tests. The silver salts gave the following results on ignition:

1. 0.1704 gram silver salt gave 0.1050 gram silver = 61.6% Ag.
2. 0.2782 gram silver salt gave 0.1796 = 64.5% Ag.
3. 0.1594 gram silver salt gave 0.1036 = 65% Ag.

The silver salt of acetic acid yields 64.67% Ag.

Sesquiterpenes and Sesquiterpene Alcohols.

Very small quantities of unidentified sesquiterpenes and sesquiterpene alcohols were observed in the highest boiling fractions.



Calythrix virgata in the Lower Burragorang Valley, New South Wales, 18/6/1932.



Field of seedlings, *Calythrix virgata*, in flower, Megalong Valley, New South Wales, 24/10/1933. (Area about $1\frac{1}{4}$ acres.)

SOME MECHANICAL PROPERTIES OF ALPINE
ASH (*EUCALYPTUS DELEGATENSIS*, R.T.B.).

PART I.

By M. B. WELCH,¹ B.Sc., A.I.C.,
Technological Museum, Sydney.

(With Plate IV and Four Text-figures.)

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

Alpine Ash,² *Eucalyptus Delegatensis*, R. T. Baker (*E. gigantea*, Hook), occurs at moderately high elevations in the southern highlands of New South Wales, and also in Victoria and Tasmania. It is an important commercial hardwood of moderate weight, and is one of the most promising New South Wales timbers which can be substituted for Oregon for scantlings. The wood is also used for a number of purposes, including furniture, interior fittings of all kinds, mouldings, general building purposes, including doors and windows, flooring, lining, weatherboards, plywood, light handles, oars and sweeps, athletic requirements and motor body work.

Comparatively few tests appear to have been made to determine the mechanical properties of the wood, at any

¹ I am indebted to the Forestry Commission of New South Wales for their courtesy in providing the material and to Mr. W. A. W. de Beuzeville, who made the selection and necessary arrangements for delivery; also to the Mechanical Engineering Department, Sydney Technical College, for the use of the testing machine, and to Mr. F. B. Shambler and other members of the Museum staff who assisted very materially in making the tests and in the computation of the results.

² This species is known as Gum-top or Gum-topped Stringybark in Tasmania, and as Woollybutt or Red Ash in Victoria. With other timbers from southern States, it is sold on the Sydney market as Tasmanian Oak.

rate as far as New South Wales is concerned. The results of three tests have been published by Nangle³ and of two tests by Warren.⁴

In December, 1925, the Forestry Commission of New South Wales provided free of cost nine logs, obtained from three trees of varying girths, namely, 9 ft. 8 ins., 6 ft. and 3 ft. 6 ins., at 5 ft. height, in order that further tests might be made. The trees were grown in close proximity to each other in the Bago State Forest, near Tumbarumba, New South Wales, and the selection was made by Mr. W. A. W. de Beuzeville, who also arranged for their dispatch to Sydney. The logs were sawn into the requisite sizes in January, 1926, and allowed to air season until October, 1928, when the mechanical tests were commenced.

It is proposed to consider first the results of the static bending tests, which were made in accordance with the procedure set down in B.E.S.A. Specification 373, 1929, entitled "Methods of Testing Small Clear Specimens of Timber". The size of the test pieces was 2" x 2" x 30", and centre loading was used.

The logs from the largest tree were marked A, B and C, A being the lowest or butt log; similarly those logs from the medium sized tree were marked D, E and F, and those from the smallest tree G, H and K; C, F and K being the top logs from the respective trees. The lengths of the individual logs varied from 12' 4" to 14'. In order that the tests might be as representative as possible, sections were taken so that they extended from the outside to the centre of each log.

³ Nangle, J.: "On Some Transverse Tests of Australian and Foreign Timbers", PROC. ROY. SOC. N.S.W., xlvii, 165, 1913.

⁴ Warren, W. H.: "Timbers for Aeroplane Construction", *Australian Forestry Journal*, v, 52, 1922.

TABLE 1.—*Mechanical Properties of Individual Logs, based on Static Bending Tests.*

| | f_1 | f | E | W. to P.L. | W. to M.L. | W. | r.p.i. | M. |
|---------------------------|--------|--------|-------|---------------|---------------|------|--------|------|
| A. Girth 8' 8". | | | | | | | | |
| Max. | 11,970 | 17,435 | 2,750 | 3.70 | 21.7 | 42.4 | 4.5 | 14.8 |
| Min. | 6,510 | 10,500 | 1,250 | 1.43 | 6.5 | 32.2 | 2.0 | 12.5 |
| Mean (104 tests) | 9,631 | 14,885 | 2,080 | 2.52 | 13.57 | 38.7 | 3.2 | 13.6 |
| B. Girth 8' 2". | | | | | | | | |
| Max. | 11,660 | 17,380 | 2,520 | 3.29 | 28.8 | 45.8 | 4.5 | 15.1 |
| Min. | 7,980 | 12,075 | 1,600 | 1.73 | 6.70 | 36.6 | 2.0 | 13.5 |
| Mean (38 tests) | 10,034 | 15,042 | 2,113 | 2.65 | 13.67 | 41.1 | 3.2 | 14.2 |
| C. Girth 7' 4". | | | | | | | | |
| Max. | 11,810 | 18,800 | 2,600 | 3.52 | 21.35 | 45.7 | 6.0 | 15.0 |
| Min. | 8,140 | 12,860 | 1,635 | 1.67 | 6.15 | 36.9 | 2.5 | 12.9 |
| Mean (50 tests) | 9,774 | 15,520 | 2,094 | 2.53 | 12.8 | 40.5 | 3.5 | 14.1 |
| D. Girth 5' 3". | | | | | | | | |
| Max. | 12,390 | 17,225 | 3,165 | 3.64 | 18.39 | 45.0 | 7.0 | 17.0 |
| Min. | 8,195 | 13,335 | 1,810 | 1.91 | 11.42 | 37.6 | 3.0 | 13.4 |
| Mean (24 tests) | 10,341 | 15,469 | 2,307 | 2.60 | 14.42 | 41.3 | 4.8 | 14.8 |
| E. Girth 4' 8". | | | | | | | | |
| Max. | 12,600 | 18,695 | 2,810 | 3.50 | 20.41 | 45.0 | 6.0 | 15.5 |
| Min. | 6,880 | 11,390 | 1,350 | 2.13 | 7.42 | 35.1 | 2.5 | 13.2 |
| Mean (19 tests) | 10,338 | 16,054 | 2,173 | 2.80 | 15.82 | 41.2 | 5.1 | 14.2 |
| F. Girth 4' 2". | | | | | | | | |
| Max. | 12,120 | 18,215 | 2,370 | 3.83 | 21.25 | 44.5 | 7.0 | 15.9 |
| Min. | 8,820 | 12,600 | 1,350 | 2.25 | 10.74 | 39.1 | 2.5 | 12.5 |
| Mean (22 tests) | 10,208 | 15,961 | 2,176 | 3.10 | 15.23 | 42.0 | 5.4 | 14.0 |
| G. Girth 3' 2". | | | | | | | | |
| Max. | 11,970 | 18,430 | 2,640 | 3.50 | 21.7 | 42.1 | 10.0 | 15.1 |
| Min. | 9,240 | 13,780 | 1,680 | 2.14 | 8.90 | 37.6 | 3.5 | 12.0 |
| Mean (26 tests) | 10,804 | 15,400 | 2,183 | 2.96 | 16.77 | 40.5 | 8.0 | 13.0 |
| H. Girth 2' 8". | | | | | | | | |
| Max. | 12,285 | 18,900 | 2,450 | 4.82 | 21.20 | 41.9 | 9.5 | 13.4 |
| Min. | 9,870 | 14,440 | 1,470 | 2.86 | 13.66 | 38.5 | 4.5 | 12.1 |
| Mean (12 tests) | 11,225 | 16,895 | 1,990 | 3.54 | 17.18 | 40.3 | 7.2 | 12.9 |
| K. Girth 2' 6". | | | | | | | | |
| Max. | 13,410 | 18,665 | 2,120 | 5.48 | 17.20 | 42.7 | 10.0 | 12.4 |
| Min. | 10,080 | 12,000 | 1,490 | 3.40 | 4.45 | 37.8 | 4.0 | 11.1 |
| Mean (12 tests) | 11,560 | 15,595 | 1,810 | 4.23 | 12.25 | 39.8 | 6.8 | 11.9 |
| Mean (307 tests) | 10,335 | 15,389 | 2,116 | 2.75 | 14.11 | 40.1 | 4.4 | 13.8 |

 f_1 = fibre stress at proportional limit in lb. per sq. in. f = equivalent fibre stress at ultimate load, or modulus of rupture, in lb. per sq. in.

E = Modulus of elasticity in 1,000 lb. per sq. in.

W. to P.L. = Work to proportional limit in inch lb. per cubic inch.

W. to M.L. = Work to maximum load in inch lb. per cubic inch.

W. = Weight per cubic foot, based on air dry volume and weight at time of test.

r.p.i. = number of growth rings per inch.

M. = Moisture per cent. at time of test.

N—December 6, 1933.

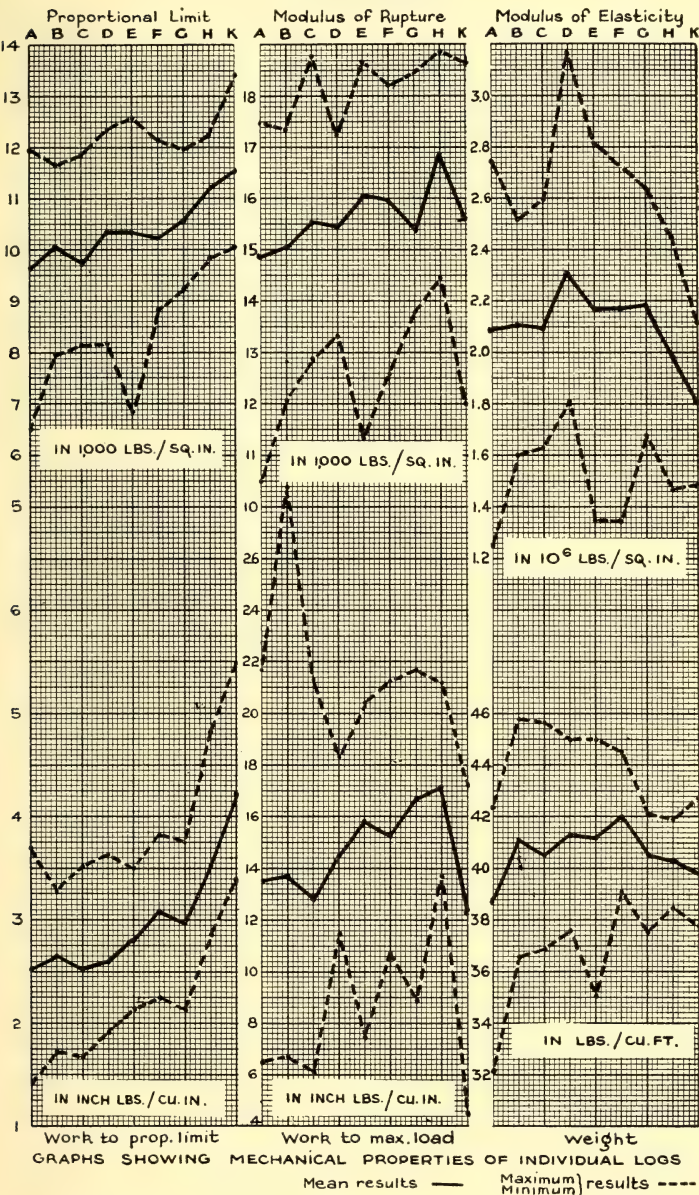
The results of the tests for the individual trees are given in Table 1. The figures given under the headings of maximum and minimum are the highest and lowest recorded for each property, and do not necessarily refer to the same test piece. The majority of the results obtained are also shown graphically in Text-figure 1.

An examination of the mean results shows that the fibre stress at the proportional limit was lowest in A log, and in the largest tree generally, than in the medium and smallest trees; the highest mean figure occurred in K log and in the smallest tree generally; this feature is more clearly shown in Text-figure 1. The actual range between the individual maximum and minimum figures for each log was from about 3,300 to 5,700 lbs. per sq. in.. For all tests a mean of 10,335 lbs. per sq. in. was found, with a maximum of 13,410 and a minimum of 6,510 lbs. per sq. inch.

Whereas there was a very definite increase in the mean proportional limit towards the top of the smallest tree, there was comparatively little variation in the different logs of the other two trees. Thirty-six per cent. of all tests fell between 10,000 and 11,000 lbs. per sq. in., and 81% were between 10,000 and 12,000 lbs. per sq. in..

The mean modulus of rupture reached a maximum in H log and a minimum in A; in general, there was comparatively little to choose between the results from C, D, G and K logs. The largest tree gave the lowest mean figures. In each tree the lowest mean result was obtained from the butt log, and in the medium and smallest tree the highest mean result was found in the middle log; in the largest tree there was a steady increase in strength towards the top. The maximum figure for all tests was 18,900 lbs., the minimum 10,500 lbs., and the mean of all tests was 15,380 lbs. per sq. inch. A considerable

FIGURE 1



degree of variation was found in the strength of the individual trees, although only sections free from material defects were used. Twenty-eight per cent. of all tests fell between 15,000 and 16,000 lbs. per sq. in., and 73% were between 14,000 and 17,000 lbs. per sq. in..

The mean modulus of elasticity was greatest in D log, and slightly higher in the medium tree than in the largest; the smallest tree showed the least stiffness in spite of its greater strength, and a steady reduction occurred towards the top. There was a variation from 3,165,000 to 1,350,000 lbs. per sq. in., with a mean of 2,116,000 lbs. per sq. in. for all tests. Thirty-four per cent. of all tests were between 2.2 and 2.3, 53% between 2.1 and 2.4, and 67% between 2.0 and 2.5 million lbs. per sq. in..

The work to the proportional limit or elastic resilience was lowest in the largest tree, with comparatively little variation between the three logs; in the medium and smallest tree the shock resisting ability increased considerably towards the top log. The mean of all tests was 2.75 inch-lbs. per cubic inch. The more slowly grown material showed a remarkably high ability to absorb energy, resulting largely from its lower stiffness.

The toughness of the wood, indicated by the work to the maximum load, was found to be highest in the middle log of each tree. It is interesting to note that K log, which showed the highest mean elastic resilience, also showed the lowest mean figure for work to the maximum load, namely, 12.25 inch-lbs. per cubic inch; the highest log mean was 17.18 inch-lbs. per cubic inch in H, and the mean of all tests was 14.11 inch-lbs. per cubic inch.

The density varied from 32.2 to 45.8 lbs. per cubic foot with a mean of 40.1 lbs. per cubic foot for all tests. It is rather surprising that the rapidly grown material in

the largest tree showed approximately the same mean density as that obtained from the smallest tree which was much slower in rate of growth. Although there was considerable variation within each log, the mean results were generally very uniform; thus B, C, D, E, G and H were all within a range of 1 lb., whilst the difference between the highest result, 42.0 lbs. for F, and the lowest, A, was only 3.3 lbs..

The rate of growth was found to range from 2 rings per inch in the largest tree, *i.e.*, an increase in diameter of the log of 1" per annum,¹ to a minimum of 10 rings per inch in the smallest tree. Taking into consideration the average rates of growth for the three trees, it is obvious that in spite of the variation in size they were all of approximately the same age, namely, about 60 years. In A and B logs the slowest rate of growth was $4\frac{1}{2}$ rings per inch.

Weight.

Since there is obviously a wide variation in the strength of the timber, it is necessary to compare the strength results with the density of the wood. As already mentioned, considerable variation was found, namely, 32.2 to 45.8 lbs. per cubic ft.. It is generally recognised that the density has an important influence on the different mechanical properties of wood.

The results of all tests have been brought together in Table 2, which shows the maximum, minimum and mean figures for each 1 lb. range from 32.45 lbs.. The effect of density on strength is more clearly shown in Text-

¹Owing to the definite seasonal variation in climatic conditions which occurs in the area from which these trees were obtained, heavy snow falling in the winter months, the growth rings can be regarded as annual.

TABLE 2.—*Effect of Weight on Strength.*

| | f_1 | f | E. | W. to P.L. | W. to M.L. | r.p.i. | M. |
|------------------------------|--------|--------|-------|---------------|---------------|--------|-------|
| 32-32.9 lb. per c. ft. | | | | | | | |
| Max. | 7,560 | 11,390 | 1,460 | 2.12 | 12.40 | 2.0 | 13.5 |
| Min. | 6,510 | 10,500 | 1,250 | 1.77 | 6.50 | 2.0 | 13.1 |
| Mean (3 tests) | 6,930 | 11,006 | 1,360 | 1.98 | 8.50 | 2.0 | 13.3 |
| 34-34.9 lb. per c. ft. | | | | | | | |
| Max. | 8,195 | 12,235 | 2,000 | 2.50 | 15.00 | 3.0 | 14.1 |
| Min. | 6,510 | 11,655 | 1,620 | 1.55 | 8.83 | 2.0 | 13.1 |
| Mean (7 tests) | 7,412 | 12,015 | 1,490 | 2.13 | 10.39 | 2.5 | 13.4 |
| 35-35.9 lb. per c. ft. | | | | | | | |
| Max. | 10,080 | 15,435 | 2,300 | 2.49 | 17.85 | 3.5 | 13.6 |
| Min. | 7,665 | 11,390 | 1,185 | 1.99 | 7.42 | 2.5 | 13.3 |
| Mean (6 tests) | 8,374 | 13,125 | 1,691 | 2.26 | 12.41 | 2.7 | 13.5 |
| 36-36.9 lb. per c. ft. | | | | | | | |
| Max. | 9,240 | 14,280 | 1,910 | 2.87 | 19.20 | 3.0 | 14.7 |
| Min. | 7,770 | 12,285 | 1,400 | 2.02 | 6.70 | 2.0 | 13.3 |
| Mean (7 tests) | 8,604 | 13,224 | 1,702 | 2.49 | 13.35 | 2.4 | 14.0 |
| 37-37.9 lb. per c. ft. | | | | | | | |
| Max. | 11,550 | 16,035 | 2,870 | 4.32 | 18.10 | 8.5 | 15.3 |
| Min. | 7,560 | 12,075 | 1,560 | 1.48 | 7.10 | 2.0 | 12.7 |
| Mean (22 tests) | 9,102 | 13,923 | 1,878 | 2.56 | 12.31 | 3.6 | 13.76 |
| 38-38.9 lb. per c. ft. | | | | | | | |
| Max. | 13,410 | 18,665 | 2,520 | 5.48 | 21.70 | 5.5 | 16.9 |
| Min. | 7,980 | 12,655 | 1,470 | 1.43 | 9.20 | 2.5 | 11.5 |
| Mean (48 tests) | 9,883 | 15,001 | 2,021 | 2.76 | 13.85 | 3.4 | 13.8 |
| 39-39.9 lb. per c. ft. | | | | | | | |
| Max. | 11,970 | 17,115 | 2,540 | 4.11 | 19.60 | 8.0 | 17.0 |
| Min. | 8,820 | 13,910 | 1,490 | 1.75 | 9.78 | 2.5 | 11.1 |
| Mean (54 tests) | 10,036 | 15,345 | 2,080 | 2.77 | 13.70 | 3.8 | 13.8 |
| 40-40.9 lb. per c. ft. | | | | | | | |
| Max. | 12,715 | 18,190 | 2,750 | 4.98 | 22.40 | 9.5 | 15.6 |
| Min. | 8,660 | 12,600 | 1,345 | 1.73 | 8.55 | 2.5 | 11.8 |
| Mean (53 tests) | 10,441 | 15,922 | 2,127 | 2.92 | 14.36 | 5.5 | 13.5 |
| 41-41.9 lb. per c. ft. | | | | | | | |
| Max. | 12,360 | 18,900 | 2,640 | 4.37 | 28.8 | 10.0 | 15.7 |
| Min. | 8,660 | 13,705 | 1,635 | 1.67 | 6.15 | 3.0 | 11.1 |
| Mean (47 tests) | 10,482 | 16,340 | 2,181 | 2.81 | 15.47 | 4.8 | 13.6 |

f_1 = fibre stress at proportional limit in lb. per sq. in.

f = equivalent fibre stress at ultimate load, or modulus of rupture, in lb. per sq. in.

E = Modulus of elasticity in 1,000 lb. per sq. in.

W. to P.L. = Work to proportional limit in inch lb. per cubic inch.

W. to M.L. = Work to maximum load in inch lb. per cubic inch.

W. = Weight per cubic foot, based on air dry volume and weight at time of test.

r.p.i. = number of growth rings per inch.

M. = Moisture per cent. at time of test.

TABLE 2.—*Effect of Weight on Strength*—continued.

| | f_1 | f | E. | W. to P.L. | W. to M.L. | r.p.i. | M. |
|--------------------------|--------|--------|-------|---------------|---------------|--------|------|
| 42-42.9 lb. per c. ft. | | | | | | | |
| Max. | 11,760 | 18,430 | 2,545 | 3.83 | 21.70 | 8.5 | 15.9 |
| Min. | 8,820 | 12,000 | 1,810 | 1.95 | 4.45 | 3.0 | 12.1 |
| Mean (23 tests) | 10,730 | 16,279 | 2,272 | 2.86 | 15.06 | 4.7 | 14.0 |
| 43-43.9 lb. per c. ft. | | | | | | | |
| Max. | 12,390 | 17,270 | 2,860 | 3.38 | 18.50 | 7.0 | 14.7 |
| Min. | 8,820 | 13,860 | 2,140 | 1.99 | 8.85 | 2.5 | 13.4 |
| Mean (19 tests) | 10,885 | 16,307 | 2,332 | 2.84 | 14.31 | 4.3 | 14.3 |
| 44-44.9 lbs. per c. ft. | | | | | | | |
| Max. | 11,340 | 18,695 | 2,810 | 3.16 | 20.41 | 7.0 | 15.4 |
| Min. | 9,870 | 14,650 | 2,120 | 2.09 | 10.80 | 3.0 | 13.6 |
| Mean (12 tests) | 10,785 | 16,687 | 2,435 | 2.64 | 15.16 | 4.8 | 14.3 |
| 45-45.9 lb. per c. ft. | | | | | | | |
| Max. | 11,550 | 18,800 | 3,165 | 3.24 | 21.35 | 6.0 | 15.5 |
| Min. | 10,500 | 16,435 | 2,240 | 2.36 | 13.60 | 3.5 | 14.4 |
| Mean (4 tests) | 10,920 | 17,510 | 2,642 | 2.73 | 16.79 | 4.5 | 14.8 |

f_1 = fibre stress at proportional limit in lb. per sq. in.

f = equivalent fibre stress at ultimate load, or modulus of rupture, in lb. per sq. in.

E = Modulus of elasticity in 1,000 lb. per sq. in.

W. to P.L. = Work to proportional limit in inch lb. per cubic inch.

W. to M.L. = Work to maximum load in inch lb. per cubic inch.

W. = Weight per cubic foot, based on air dry volume and weight at time of test.

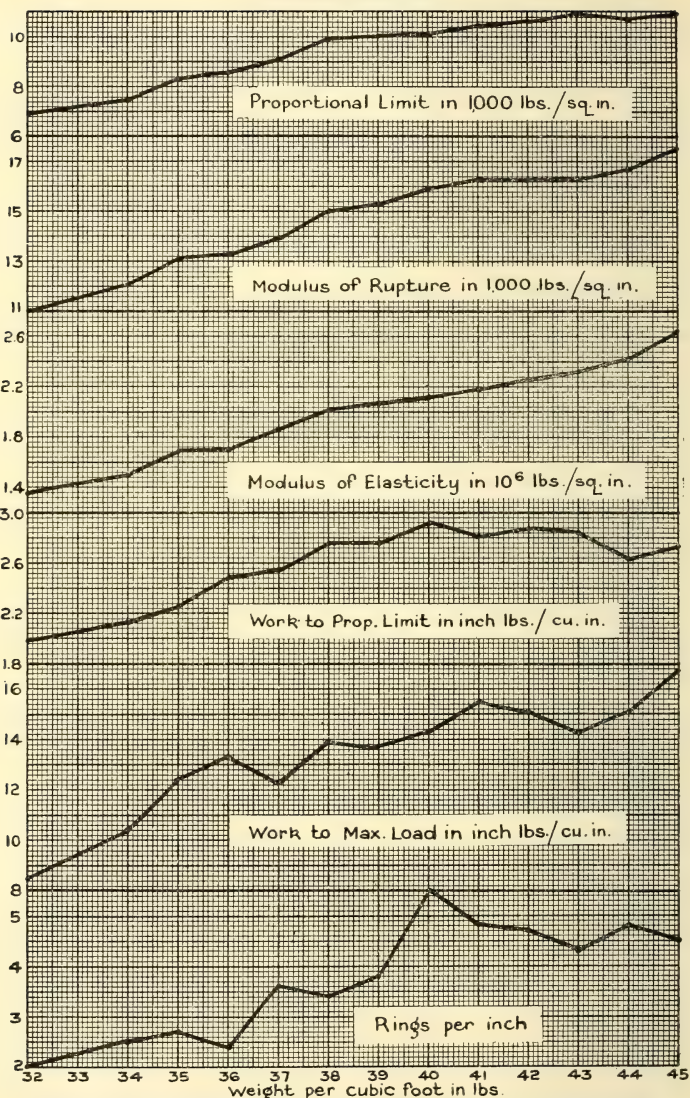
r.p.i. = number of growth rings per inch.

M. = Moisture per cent. at time of test.

figure 2, in which the mean results only are compared with the density.

The mean fibre stress at the proportional limit showed an increase, with one exception, from 6,930 to 10,920 lbs. per sq. inch throughout the range of densities, and no doubt with a larger number of tests the increase would be more uniform. The maximum and minimum results in each case indicate the range of variation above and below the mean. The modulus of rupture also showed showed a general increase with density from 11,006 to 17,510 lbs. per sq. inch, although there was comparatively little variation over the range of 41 to 44 lbs. per cubic foot. The proportional limit and the modulus of

FIGURE 2.



GRAPHS SHOWING RELATIONSHIP BETWEEN WEIGHT AND MECHANICAL PROPERTIES.

rupture usually vary almost directly as the density, although the change in strength is generally regarded as being slightly more rapid than the density.¹ In Text-figure 3, the density and modulus of rupture of all tests have been plotted. It is evident that any attempt to obtain a relationship between these two properties can only be an approximation without a much larger number of tests, owing to the number of divergent points. Many of the outliers on the right hand side are no doubt the results of weaker timber cut near the heart. The two curves give an indication of the strength probability for varying densities.

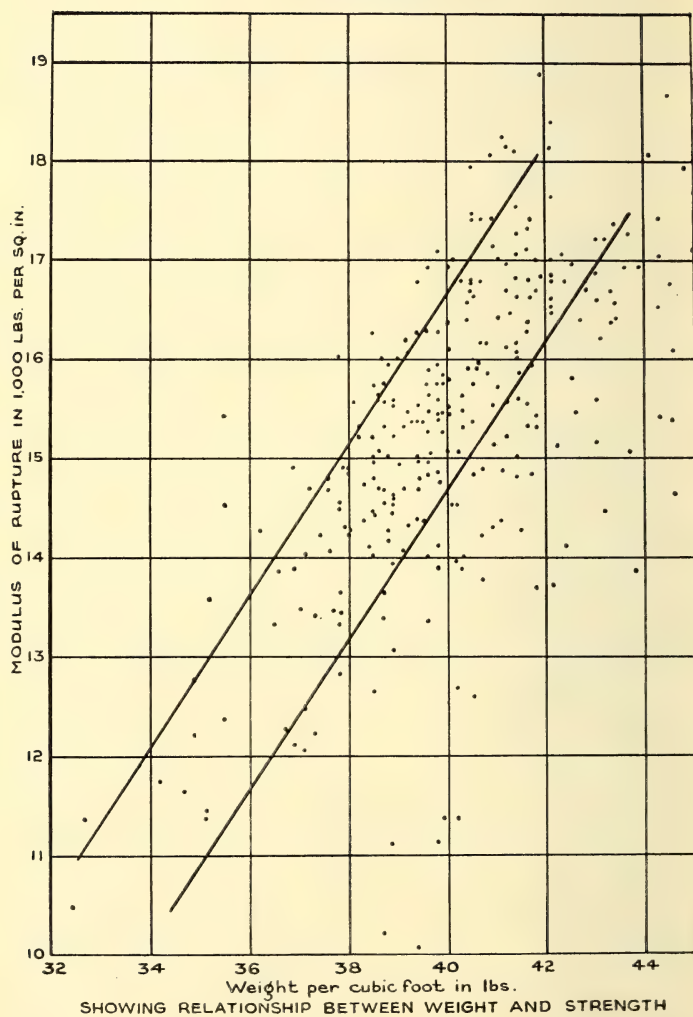
The modulus of elasticity usually varies directly as the density, and in the tests made there was an increase in the mean results from 1,360,000 to 2,642,000 lbs. per sq. inch, the gradation being more clearly seen in Text-figure 2.

The elastic resilience showed an increase from 1.98 to 2.92 inch-lbs. per cubic inch, corresponding to a density of 40-41 lbs. per cubic foot with a small reduction in the heavier tests. Whilst the increase was marked from 32.37.9 lbs. per cubic foot, there was comparatively little variation between 38 and 46 lbs. per cubic foot, although the highest individual maximum was found in the 38-39 lbs. per cubic foot range. The work to maximum load, whilst showing a general increase over the density range, gave many irregularities, especially between 40 and 45 lbs. per cubic foot.

The fastest rate of growth corresponded, as would be expected, with the lightest material, but the slowest

¹ L. J. Markwardt ("Comparative Strength Properties of Woods Grown in the United States", *Tech. Bull. U.S. Dept. of Agriculture*, No. 158, 1930) gives the strength-specific gravity relation for f_1 or f as $16,700$ or $25,700 \times G^{1.25}$ respectively, when G is the specific gravity.

FIGURE 3.



growth was found to correspond with a density of 40-41 lbs. per cubic foot; there was comparatively little variation in the rate of growth over the range from 41 to 46 lbs. per cubic foot.

The effect of density on the strength of the wood is shown in Plate IV, Figure 1. The heaviest section, weighing 42.6 lbs. per cubic ft., gave a modulus of rupture of 18,000 lbs. per sq. inch, and the splintery break is indicative of a strong tough timber with a high value for work to the maximum load. The intermediate section with a weight per cubic foot of 35.2 lbs. gave a less splintery break and a considerably lower modulus of rupture of 13,500 lbs. per sq. inch. The lightest and weakest section, weighing only 32.7 lbs. per cubic foot, shows a brittle tension failure; such wood is brash and liable to break with comparatively little warning, and is typical of wood cut near the heart.

Rate of Growth.

The effect of rate of growth on the strength of timber appears to be important, provided that there is a variation in density corresponding to the growth variation. The amount of early and late wood in the growth rings was not determined as the thickness of the cell walls, and hence density seems to be of greater importance than the amount of late wood, which may vary considerably in cell wall thickness. As a general rule, diffuse-porous and coniferous woods show a maximum strength with a medium rate of growth, rapid and slow growth usually denoting weakness, whilst ring-porous timbers become definitely weaker when growth is retarded. Alpine Ash shows a definite tendency to become ring porous, and it is interesting to examine the effect of rate of growth in relation to strength as shown

in Table 3. Owing to the preponderance of tests made on logs A, B and C, the majority of the results fall within the range of 2.5 rings per inch. With a larger number of tests of material of slower growth it is possible that the figures might be somewhat modified. The general effect of rate of growth can be more easily followed in Text-figure 4.

The fibre stress at the proportional limit showed, with one exception, a steady increase as the growth rate decreased. The mean modulus of rupture reached a maximum with 6.7 r.p.i., with a definite increase from 2.3 to 6.7 r.p.i. and again from 7.8 to 10.11 r.p.i.. Although the mean for the 2.3 r.p.i. range was only 13,574 lbs. per sq. in., individual tests, as shown by the maximum, reached a very satisfactory figure of 17,270 lbs. per sq. inch. Similarly in the 3.4 r.p.i. range an individual test gave a modulus of rupture of 18,800 lbs. per sq. in.. Extremely rapid growth was therefore by no means synonymous with weakness, although generally the highest results for strength were obtained from wood with 6.11 r.p.i.. The modulus of elasticity did not show any very marked response to rate of growth, the results from 3 to 9.9 r.p.i. all being in the vicinity of 2,100,000 lbs. per sq. inch. The highest mean result obtained was from the 10.11 r.p.i. range and the lowest from the 2.3 r.p.i. range.

The work to the proportional limit increased, with one exception, over the 2.3 to 7.8 r.p.i. range and then gradually decreased again to the 10.11 r.p.i. range. The work to the maximum load also increased with one exception from 2.3 to the 8.9 r.p.i. range, and then decreased to the 10.11 r.p.i. range. It seems therefore that the greatest toughness is to be found in material with a rate of growth of 6.10 r.p.i.. Density increased from 37.5 lbs.

TABLE 3.—*Effect of Rate of Growth on Strength.*

| | f_1 | f | E. | W. to P.L. | W. to M.L. | W. | M. |
|-------------------------|--------|--------|-----------|---------------|---------------|-------|------|
| 2-2.9 r.p.i. per inch | | | | | | | |
| Max. | 11,660 | 17,270 | 2,250,000 | 3.40 | 19.20 | 43.7 | 15.3 |
| Min. | 6,510 | 10,500 | 1,185,000 | 1.55 | 6.50 | 32.4 | 12.9 |
| Mean | 8,780 | 13,574 | 1,804,000 | 2.43 | 12.10 | 37.53 | 13.9 |
| (40 tests) | | | | | | | |
| 3-3.9 r.p.i. per inch | | | | | | | |
| Max. | 11,760 | 18,800 | 2,740,000 | 3.56 | 28.80 | 45.7 | 15.6 |
| Min. | 7,560 | 11,495 | 1,345,000 | 1.43 | 7.10 | 34.7 | 12.7 |
| Mean | 9,691 | 15,076 | 2,091,000 | 2.44 | 13.54 | 39.7 | 14.0 |
| (118 tests) | | | | | | | |
| 4-4.9 r.p.i. per inch | | | | | | | |
| Max. | 11,985 | 18,165 | 2,870,000 | 4.82 | 22.40 | 45.8 | 16.9 |
| Min. | 8,195 | 12,335 | 1,470,000 | 1.73 | 7.90 | 37.6 | 11.5 |
| Mean | 10,382 | 15,721 | 2,155,000 | 2.80 | 13.62 | 40.8 | 14.0 |
| (58 tests) | | | | | | | |
| 5-5.9 r.p.i. per inch | | | | | | | |
| Max. | 12,075 | 18,190 | 2,330,000 | 4.10 | 19.29 | 43.4 | 14.7 |
| Min. | 8,660 | 14,015 | 1,470,000 | 2.06 | 10.71 | 38.5 | 11.5 |
| Mean | 10,450 | 15,945 | 2,051,000 | 3.06 | 14.78 | 41.1 | 14.1 |
| (21 tests) | | | | | | | |
| 6-6.9 r.p.i. per inch | | | | | | | |
| Max. | 12,600 | 18,695 | 3,165,000 | 3.66 | 20.60 | 45.0 | 15.4 |
| Min. | 9,450 | 15,435 | 1,808,000 | 2.25 | 11.71 | 39.6 | 12.5 |
| Mean | 10,931 | 16,848 | 2,120,000 | 2.90 | 16.32 | 42.2 | 13.8 |
| (21 tests) | | | | | | | |
| 7-7.9 r.p.i. per inch | | | | | | | |
| Max. | 13,410 | 18,900 | 2,700,000 | 5.48 | 21.25 | 44.5 | 15.7 |
| Min. | 9,450 | 12,000 | 1,680,000 | 2.14 | 4.45 | 38.5 | 11.6 |
| Mean | 11,190 | 16,378 | 2,153,000 | 3.71 | 15.82 | 40.9 | 13.4 |
| (23 tests) | | | | | | | |
| 8-8.9 r.p.i. per inch | | | | | | | |
| Max. | 12,715 | 18,430 | 2,640,000 | 4.98 | 21.70 | 42.1 | 13.5 |
| Min. | 9,240 | 14,700 | 1,490,000 | 2.44 | 10.44 | 37.8 | 11.8 |
| Mean | 11,072 | 16,254 | 2,119,000 | 3.38 | 16.61 | 40.6 | 12.7 |
| (15 tests) | | | | | | | |
| 9-9.9 r.p.i. per inch | | | | | | | |
| Max. | 11,760 | 17,430 | 2,370,000 | 3.82 | 19.40 | 41.4 | 13.3 |
| Min. | 9,870 | 15,805 | 1,700,000 | 2.78 | 13.66 | 40.0 | 12.1 |
| Mean | 11,360 | 16,689 | 2,074,000 | 3.31 | 16.51 | 40.6 | 12.9 |
| (5 tests) | | | | | | | |
| 10-10.9 r.p.i. per inch | | | | | | | |
| Max. | 12,360 | 18,165 | 2,640,000 | 4.27 | 20.80 | 41.8 | 13.2 |
| Min. | 10,710 | 15,725 | 1,960,000 | 2.50 | 9.12 | 41.0 | 11.1 |
| Mean | 11,542 | 16,747 | 2,337,000 | 3.16 | 15.23 | 41.3 | 12.1 |
| (4 tests) | | | | | | | |

f_1 = fibre stress at proportional limit in lb. per sq. in.

f = equivalent fibre stress at ultimate load, or modulus of rupture, in lb. per sq. in.

E = Modulus of elasticity in 1,000 lb. per sq. in.

W. to P.L. = Work to proportional limit in inch lb. per cubic inch.

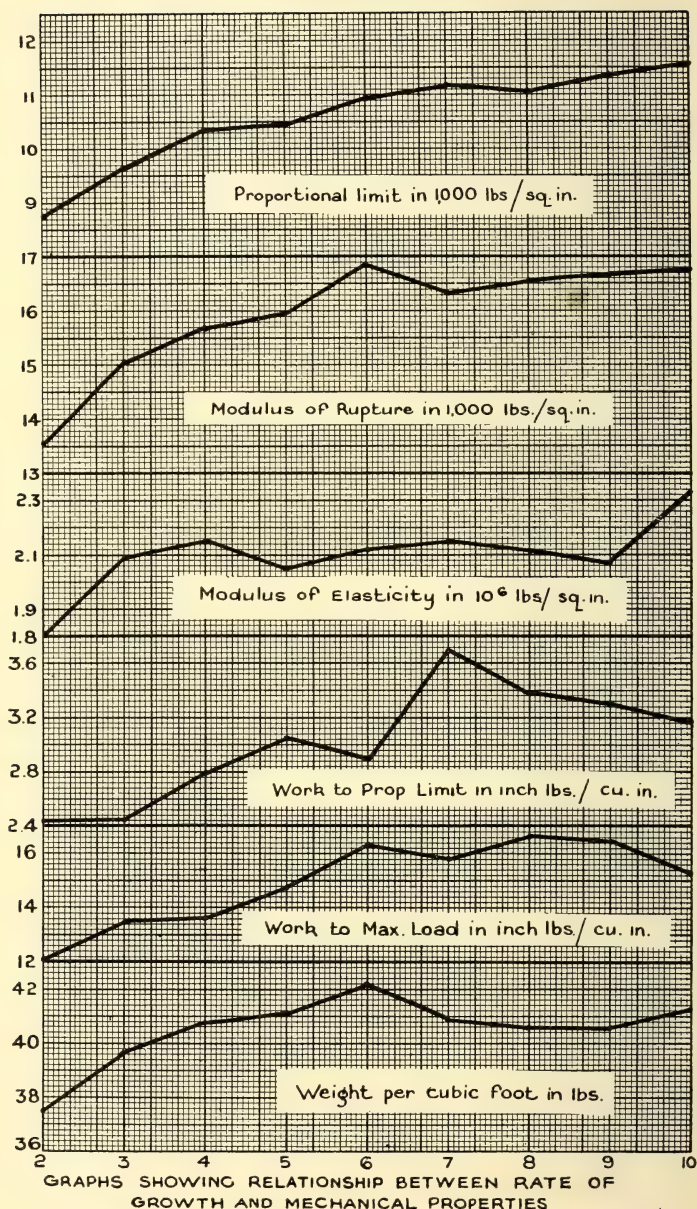
W. to M.L. = Work to maximum load in inch lb. per cubic inch.

W. = Weight per cubic foot, based on air dry volume and weight at time of test.

r.p.i. = number of growth rings per inch.

M. = Moisture per cent. at time of test.

FIGURE 4.



in the 2·3 r.p.i. range, to 42·2 lbs. with 6·7 r.p.i., and then showed a slight fall in the more slowly grown material. Here again individual tests in the 2·3 r.p.i. range showed a maximum of 43·7 lbs. per cubic foot, whilst the minimum density in the 8·9 r.p.i. range was only 37·8 lbs..

Although, in general, density varied directly as the number of growth rings per inch, there were too many exceptions to enable any relationship to be established between the two variables.

The variation in the rate of growth is clearly indicated in Plate IV, Figure 2. (a) is taken from log G and is typical of the slow growth found in the smallest tree; the weight of the section shown is 42·1 lbs. per cubic ft.. (b) is a portion of log E, and shows the more rapid growth of the medium tree; the weight is 41·7 lbs. per cubic ft.. (c) is from log C and weighs 36·8 lbs. per cubic ft.; the rate of growth is decidedly more rapid than is typical of the smaller trees. (d) is from log A and shows a moderately dense timber of 38·2 lbs. per cubic ft., although the rate of growth is $3\frac{1}{2}$ rings per inch. (e) and (f) are taken from logs C and A respectively, and show extremely rapid growth; the densities are 35·9 and 33·1 lbs. per cubic ft..

SUMMARY.

A series of static bending tests were made on nine logs of Alpine Ash, *Eucalyptus Delegatensis*, from three trees of varying girths. The results did not show any uniform increase in strength towards the top of the tree, and in some instances the wood was decidedly weaker in the uppermost log than in the lowest.

The weight per cubic foot varied from 32·46 lbs. with a mean of 40·1 lbs., and except for wood of low density,

the results proved that Alpine Ash possesses considerable strength with a high modulus of elasticity, whilst the toughness, as indicated by the work to the maximum load, and also the elastic resilience, is very satisfactory. The fibre stress at the proportional limit, modulus of rupture and modulus of elasticity increased comparatively regularly with the density, but the effect of density was more irregular on the work to the proportional limit and to the maximum load.

The rate of growth varied from 2-10 growth rings per inch, the maximum density and strength (modulus of rupture) being obtained at 6 r.p.i., although the maximum values for fibre stress at the proportional limit and modulus of elasticity were found in the wood of slowest growth. The greatest shock-absorbing ability was found in wood of somewhat slower growth. Although there were numerous exceptions, wood showing less than 3 growth rings per inch, especially if cut near the heart and of low density, was unsatisfactory with regard to strength.

EXPLANATION OF PLATE IV,

Fig. 1.—Portions of three test pieces showing types of failures; the contrast between the fibrous break characteristic of the denser wood and the brash failure of the lighter wood is clearly shown. The weight per cubic foot and modulus of rupture are indicated on each specimen.

Fig. 2.—End view of several test pieces showing varying rates of growth. For explanation see text, p. 401.

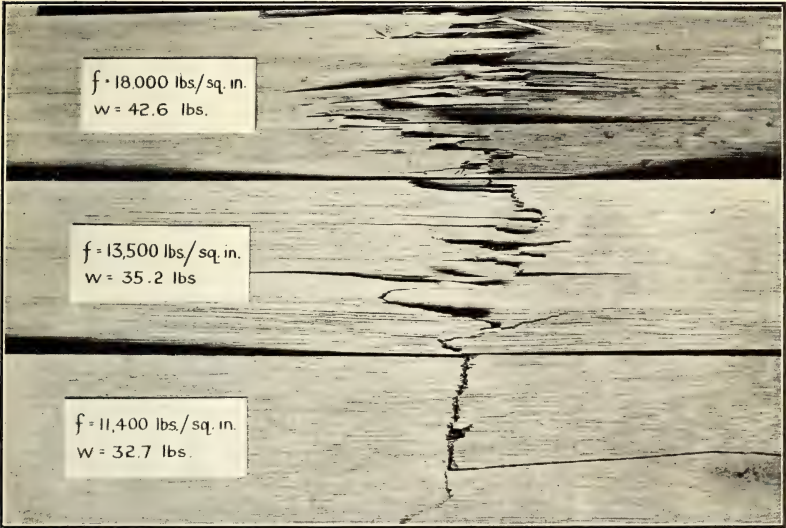


Fig. 1.

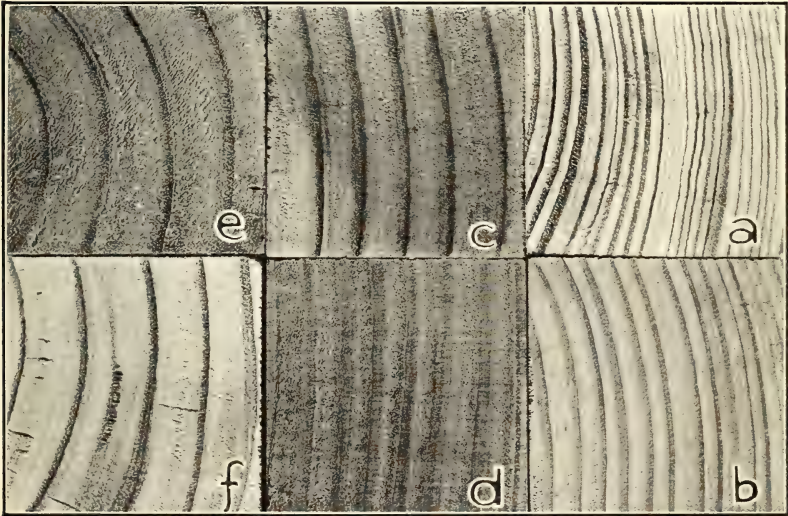


Fig. 2.

NOTE ON THE LONGEVITY OF SPORES OF THE
FUNGUS *UROCYSTIS TRITICI* KOERN.

By R. J. NOBLE, Ph.D., M.Sc., B.Sc.Agr.,
Biologist, Department of Agriculture, Sydney.

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

Very little information is available on the longevity of fungous spores which have been kept under controlled environmental conditions for long periods, although observations in this connection are of value insofar as they have a bearing on the parasitism of fungi which may cause disease in plants. McCrea⁽⁶⁾ drew attention to the paucity of reliable records on longevity of fungous spores, when she reported on the germination of spores of *Aspergillus oryzae* and *Rhizopus nigricans* which had been preserved in a sealed tube for 22 years. Maneval⁽⁸⁾ has recorded that the spores or mycelium of a number of species of *Fusarium* remained viable in test tubes for 7 to 8 years. McAlpine⁽⁵⁾ (p. 22) made some observations on longevity of spores of the Smut fungi, and further references in this connection have been reviewed by Güssow and Conners⁽³⁾ (pp. 4, 5). Such observations generally refer to herbarium material, which is stated to have been kept dry. According to Smith,⁽¹³⁾ the spores of some myxomycetes may remain viable for approximately 32 years, and it would appear that records of longevity may be established also for many fungous spores, provided that they are preserved under suitable environmental conditions.

In a study of viability of uredospores, Maneval⁽⁹⁾ and Peltier⁽¹²⁾ reported that longevity was favoured by exposure of the spores to medium relative humidities. Lambert⁽⁴⁾ reviewed previous studies on the viability of the teliospores of *Puccinia graminis* and found that capacity for germination was retained best when the material was kept dry under low temperature conditions.

The spores of species of the *Peronosporales* are typically short lived and previous investigators have indicated that retention of viability was favoured by exposure to moist conditions. Angell and Hill,⁽¹⁾ however, have shown that the spores of the Tobacco Blue Mould fungus* may remain alive for several weeks, not only under cool, moist conditions, but also when held over fused calcium chloride flakes in a desiccator at higher temperatures.

There are but few observations on the longevity of spores of *Urocystis tritici*, the fungus causing Flag Smut of wheat. McAlpine⁽⁵⁾ (p. 95) recorded an instance in which spores of this fungus, approximately two years old, did not cause infection in wheat, although he did not consider the test conclusive. Griffiths⁽²⁾ found that spores of *U. tritici* were viable after having been kept for four years in the laboratory. Verwoerd⁽¹⁵⁾ (pp. 33 to 35) also reported viability of spores which were four to five years old. Infection resulted with spores from herbarium material and with those which had been kept in dry and in moist soils, although the percentage infection decreased progressively each year, as the spores became older.

Previous studies by the writer^{(10) (11)} indicated that viable spores of *U. tritici* did not germinate readily in

* *Peronospora tabacina* Adam.

the laboratory, yet germination could be ensured by the adoption of suitable technique. Subsequently, germination tests were completed with spores which had been kept under herbarium conditions for periods of three to nine years, but in no instance did any of the spores germinate. It was suggested that environmental factors may have had a marked influence on the viability of the spores.

The history of certain areas in the wheat belt of New South Wales provides strong presumptive evidence of the longevity of the spores of *U. tritici*. McDiarmid⁽⁷⁾ reported an instance of Flag Smut infection in a crop of wheat seven years after a crop of wheat had previously been grown on the same land. Such evidence is not conclusive, as not only may spores have been blown on to the land in the meantime, the seed may have become contaminated after pickling, and even more important is the fact that horses or sheep may have fed on hay, chaff, or stubble affected with Flag Smut and the land may have become re-infested with spores which had passed through the alimentary tract. Tests conducted by Verwoerd⁽¹⁵⁾ (pp. 21, 22) and unpublished data from experiments conducted by the writer in co-operation with the Veterinary Research Station, Glenfield, New South Wales, in 1928, demonstrated that the spores of *U. tritici*, after passage through the alimentary tract of horses and sheep, were capable of causing infection in wheat, thus confirming a report of a test by McAlpine⁽⁵⁾ (p. 96) which was considered inconclusive.

In order to secure further data on the longevity of spores of *U. tritici*, a series of tests was arranged to determine the effect of various relative humidities on

germination capacity, and observations have been recorded during the past ten years.

EXPERIMENTAL.

Specimens of wheat (var. Cleveland) affected with Flag Smut were collected at Bathurst, New South Wales, on November 7, 1923. The leaves were pressed between absorbent papers in a plant press for several days and were then removed and cut into small portions approximately 10 mm. in length. On November 14, 1923, leaf portions containing spores of *U. tritici* were placed in small paraffined cardboard trays which were suspended from corks over approximately 100 cc. of sulphuric acid in various concentrations in wide-mouthed bottles of approximately 250 cc. capacity.

The series of sulphuric acid solutions was selected to provide atmospheres of varying relative humidities in accordance with the data provided by Stevens⁽¹⁴⁾ and Wilson.⁽¹⁶⁾ After suspension of the spore-bearing tissues over the solutions, the bottles were sealed with paraffin wax. Three series of containers were prepared in this manner. Germination tests were made at fairly frequent intervals during the first few years, but in order to conserve material, later examinations were made at yearly intervals. No material was available for test in the first series after 1929, and observations were then continued with the spores contained in the second series.

The bottles were kept in a dark cupboard and the corks were removed momentarily for extraction of the spores, which were gently shaken from the leaf portions on to the surface of approximately 5 cc. of distilled water in Syracuse dishes at each examination. The containers were then immediately resealed. After a pre-

soak period of several days, germination was stimulated by the addition of a thin film of benzaldehyde which was transferred to the water on the tip of a platinum needle in accordance with the method previously described by the writer.⁽¹¹⁾

At the commencement of the experiment in 1923, facilities were not available for maintenance of the preparations at constant temperature. Room temperature records have been available for the past three years, and although the lowest recorded temperature during this period was 13° C., and the highest 31° C., the averages of the lowest temperatures recorded each month for each yearly period have been 18·3°, 18·1° and 19° C., and the corresponding averages of the highest temperatures have been 23·8°, 23·3° and 24° C. These figures provide some indication of the temperature conditions to which the spores have been exposed throughout the period of the test. Although accurate data are thus not available as to the actual temperatures to which the spores have been exposed, it may be seen from the data compiled by Wilson⁽¹⁶⁾ that there is relatively little change in the relative humidity conditions within the temperature range indicated above. As indicated in the table compiled by Stevens,⁽¹⁴⁾ the widest variations in saturation deficit within the temperature range occur in the low humidity series, but, as shown in Table I, it is in this series that there has been least variation in capacity for germination.

The density of the sulphuric acid solutions was checked at the conclusion of examination of spores in the first series of containers (Table I). The corresponding relative humidities at 25° C. are those indicated on the curve compiled by Wilson,⁽¹⁶⁾ and these values

may be considered as the maximum humidities to which the spores were exposed, as slight amounts of atmospheric moisture may have been taken up by the solutions during the course of the tests.

TABLE I.—*Annual Germination of Spores of Urocystis tritici collected on November 7, 1923, and maintained under a series of relative humidity conditions at temperatures 13°–31° C.*

| Density of Sulphuric Acid Solution at 23° C. | Approx. Per Cent. Relative Humidity at 25° C. | Germination Result. | | | | | | | | | |
|--|---|---------------------|-----|-----|-----|----------------|------------------|-----|-----|-----|-----|
| | | '24 | '25 | '26 | '27 | '28 | '29 ¹ | '30 | '31 | '32 | '33 |
| 1.760 | 0.1 | + | + | + | + | + | + | + | + | + | + |
| 1.532 | 11.9 | + | + | + | + | + | + | + | + | + | + |
| 1.418 | 31.2 | + | + | + | + | + | + | + | + | + | + |
| 1.407 | 33.5 | + | + | + | + | + | + | + | + | + | + |
| 1.331 | 50.0 | + | + | + | tr. | tr. | tr. | 0 | 0 | 0 | 0 |
| 1.269 | 64.0 | + | + | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.234 | 72.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1.131 | 89.0 | 0 | 0 | 0 | 0 | — ² | — | 0 | 0 | 0 | 0 |

¹Final examination of spores in first series of containers.

²Spore material exhausted.

+ = more than 50% germination.

tr. = trace, less than 1% germination.

0 = no germination observed.

The final examination of spores was completed on November 11, 1933, and, as indicated in Table I, the spores in the low relative humidity series still germinated vigorously. During 1924 and 1925, germination commenced first in the 50% and 64% relative humidity series, but under the conditions of this experiment, viability was not maintained. In the higher humidities, the leaf portions soon became contaminated with mould (mainly *Penicillium* sp.) and the spores did not flow freely on being transferred to the Syracuse dishes for examination. No germination was observed at any time in the 72.5 and 89% relative humidity series.

In a previous test conducted by the writer,⁽¹¹⁾ spores of *U. tritici* which had been kept in the laboratory for eight months were subsequently subjected to a series of

relative humidity conditions for six months. Germination tests were conducted at monthly intervals, and it appeared as if medium relative humidity conditions favoured retention of viability. It was not possible to make further observations at the time, and the test was discontinued.

In the present experiment, which is still in progress, it has been established that the spores of *Urocystis tritici*, when kept under relatively dry conditions, will retain capacity for germination for at least ten years.

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THE VOLUMETRIC MICRO DETERMINATION OF PERCHLORATES WITH METHYLENE BLUE AND PICRIC ACID.

By ADOLPH BOLLIGER,* Ph.D.

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

Principle: Perchlorates form with methylene blue chloride, usually called methylene blue, a methylene blue perchlorate (3-6 tetramethyldiamino-thiazine-perchlorate) which is only slightly water-soluble. By adding a known excessive amount of methylene blue the excess can be determined by titrating against standardized picric acid as described in a previous communication (Bolliger, A., (PROC. ROY. SOC. N.S.W., 67: 240, 1933).

Reagents: 0.01 N methylene blue and 0.01 N. picric acid are prepared and standardized as described in the previous paper.

If the relative strengths of the methylene blue and the picric acid solutions are known they can be easily controlled against a perchlorate solution of known titre as described under part C in this paper. Such a solution may be prepared either by dissolving a known quantity of potassium perchlorate in a known volume of water or by titrating sufficiently dilute perchloric acid with standard alkali.

* I desire to express my sincere thanks to the Board of Directors of the Sydney Hospital for extending to me the facilities necessary for the completion of this investigation, and to Dr. Keith Inglis and Dr. H. S. Wardlaw for their sympathetic assistance in arranging for these facilities to be available.

P—December 6, 1933.

Procedures: Varying with the amount of perchlorate to be determined different procedures are recommended.

A. Amounts of Perchlorate Below 1 mgm.

The aqueous perchlorate solution is transferred to a cylindrical separatory funnel of suitable size containing a few cc. of chloroform. A known excess of 0.001 N methylene blue and a few drops of 20% solution of acid sodium phosphate are then added. The methylene blue perchlorate formed is extracted with a volume of chloroform about five times as large as the aqueous layer. Methylene blue perchlorate dissolves in chloroform to a small extent, producing a blue solution. Methylene blue itself, however, is practically insoluble in chloroform in the dilution present.

Complete extraction of the methylene blue perchlorate formed is necessary, or too high a value will be obtained by titrating the excess methylene blue. Therefore several extractions have to be performed till the chloroform remains practically colourless.

In general, the separation between the aqueous layer and the chloroform is satisfactory and no losses occur if one waits for complete separation. The danger of loss increases with the use of 0.01 N. or more concentrated methylene blue solutions or with the addition of a very large excess of the dye. An excess amounting from 25 to 50% was found to be optimal. If it happens that not sufficient methylene blue has been added, this will be indicated by the paleness of the blue colour of the aqueous layer after the first extraction. In such a case more methylene blue has to be added, but the minimum excess should amount to at least 1 cc. of 0.001 N methylene blue or the result may be too low. Also, too

low results will be obtained if the perchlorates are present in a dilution below 0.0005 N.

After removal of the methylene blue perchlorate, the remaining excess of methylene blue is determined by titration with 0.001 N picric acid. The technique is the same as the one described in the previous paper on the volumetric determination of methylene blue with picric acid.

B. Amounts of Perchlorate of 1 mgm. or More.

On account of the small solubility of methylene blue perchlorate in chloroform it is advisable here to remove as much of it as possible by crystallization. The solubility of methylene blue perchlorate in water is 7.66 mgm. per 100 gms. at 18° C. (Hofmann, K. A., Hartmann, F., and Hofmann, U., *Ber. Deutsch Chem. Ges.*, 1925, 58: 2748). Therefore one aims at concentrated perchlorate solutions, using preferably a known amount of 0.01 N methylene blue solution. After the two solutions are mixed, they are allowed to stand in the ice-box over night in order to obtain the maximum amount of crystal formation.

The methylene blue perchlorate which crystallizes from dilute solutions in fine opalescent needles of greenish metallic appearance is separated from the excess methylene blue solution by centrifuging. Then either the whole or an aliquot part of the supernatant fluid is transferred to a separatory funnel containing chloroform.

The methylene blue perchlorate which remains in solution is extracted with chloroform, but to ensure rapid and complete separation of the aqueous layer from the chloroform layer it is advisable to dilute the methylene blue solution to about 0.001 N. If the methylene blue perchlorate which has failed to crystallize out is not

removed in this way the final result will be too low by about 0.4 to 0.5 mgm. of perchlorate (see Table I). Therefore the extraction with chloroform can only be dispensed with when using large amounts of perchlorate. The final titration with 0.001 N picric acid is the same procedure as described previously. If the methylene blue perchlorate still in solution has not been removed beforehand by chloroform extraction, it will necessarily take more chloroform washing during the titration to obtain a sharp end-point.

C. Double Precipitation Method for Amounts of Perchlorate Exceeding 1.0 mgm.

The time-consuming removal of methylene blue perchlorate can be dispensed with, if the excess of the methylene blue added is precipitated with an excess of picric acid. After titrating off the combined precipitation, the remaining excess of picric acid is determined in an aliquot part of the filtrate by titration with methylene blue.

Since methylene blue perchlorate is slightly soluble, it will react to some extent with a dilute solution of picric acid giving methylene blue picrate and perchloric acid. The solution becomes greenish, but this colour, being due to methylene blue picrate, may be removed by chloroform extraction. The presence of free perchloric acid is demonstrated by the acid reaction after the removal of the picric acid and by the formation of methylene blue perchlorate with methylene blue after chloroform extraction of the methylene blue picrate.

For example, after adding solid methylene blue perchlorate to an approximately 0.003 N picric acid solution, the amount of methylene blue picrate formed in one hour was 3 mgm. %, while in twenty-four hours

it amounted to 13 mgm. %. After further standing no more methylene blue picrate was formed. Furthermore, it was found, as would be expected, that the formation of methylene blue picrate increased with increasing dilutions of picric acid. In a concentrated picric acid solution practically none goes into solution.

In order, therefore, to obtain satisfactory results the following precautions have to be applied:

1. The solutions used should be preferably 0.01 N and in any case not below a concentration of 0.005 N.
2. The methylene blue perchlorate formed must be crystallized out as completely as possible.
3. The filtering off of the two precipitates, *viz.*, methylene blue perchlorate and methylene blue picrate, must be rapid.
4. To avoid any loss due to the solubility of picric acid in chloroform in concentrations higher than 0.0005 N, the filtrate has to be sufficiently diluted.

The analytical procedure is demonstrated by the following examples: To 1 cc. of a 0.05 N potassium perchlorate (2.76 mgm. KClO_4) in a test tube, 4 cc. of 0.01 N methylene blue are added. The mixture after shaking is put in the ice-box overnight. The next morning a fast filter of suitable size (Whatman No. 41) is prepared. Then from a burette, 4 cc. of a 0.01 N solution of picric acid are added, care being taken to add the solution rapidly and to mix the picric acid with the methylene blue as little as possible during the process. Then the contents are shaken vigorously a few times and immediately afterwards are poured on the filter, which has been previously prepared. After about 6 cc. of the filtrate, of yellow colour, have been obtained the

remainder is discarded. Five cc. of the filtrate are then transferred to a separatory funnel containing about 20 cc. of chloroform and 40 cc. of water. Then the titration with 0.001 N methylene blue is performed as described, but the chloroform is not renewed until very near the end-point. It requires with 5 cc. of filtrate, 11.0 cc. of 0.001 N methylene blue before the blue colour becomes stationary in the aqueous layer. Therefore the total of the 9 cc. of picric acid solution present would have used up 19.8 cc. of 0.001 N methylene blue. With the use of an amount of picric acid solution equal to that of methylene blue solution, the number of cc. of 0.001 N methylene blue necessary to neutralize the excess picric acid represents the amount of 0.001 N methylene blue combined with the perchlorate. Consequently in the example 2.73 mgm. of KClO_4 were found, *i.e.*, 19.8 multiplied by 0.138 mgm., the millinormal weight of potassium perchlorate.

In general an excess of at least 20% of methylene blue should be added to the perchlorate. After the methylene blue perchlorate has been crystallized out it can easily be judged from the colour of the fluid whether a substantial excess of methylene blue is present. It is not necessary, however, to add an amount of picric acid equal to that of methylene blue, but the minimum excess should also be in the vicinity of about 20%. In such cases the result (x) as expressed in cc. of 0.01 N perchlorate will be obtained by subtracting the number of cc. 0.01 N methylene blue used in the titration (c) from the cc. 0.01 N picric acid added (b). The figure obtained represents the amount of picric acid that was necessary to neutralize the excess methylene blue added to the perchlorate solution and has to be subtracted

from the total of methylene blue added in the first place (a). $x = a - (b - c)$.

As shown in the table, known amounts of perchlorates exceeding 1 mgm. can be recovered with a maximum error of 2%. With amounts below 1 mgm. the error will be larger.

TABLE I.—*Potassium Perchlorate Recovered by Methods A, B, and C.*

| Solution Containing KClO ₄ mgm. | Found KClO ₄ mgm. | Error %. | Method. |
|---|---------------------------------|----------|----------------|
| 0.025 | 0.0238 | -5.0 | A |
| 0.05 | 0.049 | -2.0 | A |
| 0.1 | 0.098 | -2.0 | A |
| 0.1 | 0.099 | -1.0 | A |
| 0.4 | 0.4 | ±0 | A |
| 1.0 | 0.99 | -1.0 | A |
| 2.0 | 2.01 | +0.5 | B |
| 5.0 | 5.04 | +0.8 | B |
| 10.0 | 10.06 | +0.6 | B |
| 10.0 | 9.5 | -5.0 | B ¹ |
| 50.0 | 49.6 | -0.8 | B ¹ |
| 1.386 | 1.37 | -1.2 | C |
| 1.386 | 1.41 | +1.7 | C |
| 6.93 | 6.90 | -0.5 | C |
| 10.39 | 10.42 | +0.3 | C |

¹Without complete removal of methylene blue perchlorate.

This last procedure (C), although a double indirect method, requires only single filtration and one titration. It is less time-consuming than the methods described under A and B. The main difficulty with these methods lies in the small solubility of methylene blue perchlorate in chloroform. Therefore we tried to find a thiazine or azine dye which formed a perchlorate readily soluble in chloroform. Of all the dyes at our disposal (thionine, toluidine blue, methylene green, neutral red, safranin) only methylene green was found to form a perchlorate more chloroform soluble than the methylene blue perchlorate, but in contrast to methylene blue, methylene green is not available in chemically pure form and its perchlorate is also more water-soluble.

All the three methods described for the determination of perchlorate can also be applied to the determination of potassium whenever this cation is isolated as perchlorate.

SUMMARY.

A method is given for the quantitative micro estimation of perchlorates. By the addition of an excess of methylene blue the perchlorates are converted into methylene blue perchlorate. The excess of methylene blue is titrated with picric acid. According to the amount of perchlorate likely to be present, three modifications of the technic of this estimation are given.

The Gordon Craig Urological Research Laboratory,
Department of Surgery,
University of Sydney.

THE ACTION OF NITROUS ACID ON
DIMETHYLANILINE.

PART II.

By JOHN CAMPBELL EARL, D.Sc., Ph.D.,
and ALAN WILLIAM MACKNEY.

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

Among the products recorded as being formed during the action of nitrous acid on dimethylaniline (JOURN. ROY. SOC. N.S.W., 1933, 67, 232) was one decomposing at 157.8° C., and giving on analysis 21.3 per cent. of nitrogen. On closer examination this proved to be the nitrate of p-nitroso-dimethylaniline (N, 19.7 per cent.). On treatment with sodium carbonate solution it gave a quantitative yield of the free base and it was identical with the product formed by the direct addition of nitric acid to the base. Repeated analyses for nitrogen gave inconsistent results, namely, 20.1, 21.1, 21.3, 20.5, 21.4, 20.0, 19.9, 20.0, 19.5, 19.9, 21.2 per cent. This difficulty was encountered previously by Torrey (*Am. Chem. Jour.*, 1902, 28, 120).

Here again, therefore, is an example of the marked tendency of nitrous acid to act as an oxidising agent when stronger acids are not present to influence its action in other directions.

Further work on this subject is being carried out, but the present note is published to record the above-mentioned identification of p-nitroso-dimethylaniline nitrate.

X RAY DIFFRACTION STUDIES OF THE CRYSTALLISATION OF AMORPHOUS SILICA.

By F. P. DWYER, M.Sc.,
and D. P. MELLOR, M.Sc.

(Read before the Royal Society of New South Wales, Dec. 6, 1933.)

Various scattered and not very concordant observations on the crystallisation of vitreous silica and silica gel in the presence of different fluxes below a temperature of 870° C. are to be found in the literature. The earliest experiments, made at somewhat uncertain temperatures by Hautefeuille (*Bull. Soc. Min. France*, 4: 241, 1881) indicated that quartz was the crystalline modification of silica so produced. Later, Day and Shepherd (*J. Amer. Chem. Soc.*, 28: 1089, 1906), observing that tridymite was formed from vitreous silica in the presence of various fluxes at 800° C., erroneously fixed the quartz-tridymite transition at this value. The stability ranges of the principal forms of silica, quartz, tridymite and cristobalite were first accurately defined by Fenner (*Amer. Journ. Science*, 36: 331, 1931). Below 870° C. quartz is the stable modification of silica. However, Fenner noted that silica gel, when heated with sodium tungstate at temperatures ranging from 800 to 850° C. for several hours, crystallised as tridymite, which then further changed into quartz, the stable phase, but he could not detect cristobalite as an intermediate phase between amorphous silica and tridymite.

Since the work of Fenner, contradictory results regarding the crystallization of amorphous silica have been obtained by Braesco (*Ann. Physique*, 14: 5, 1920), Houldsworth and Cobb (*Trans. Eng. Ceramic Soc.*, 21: 227, 1922), and Day and Shepherd (*J. Amer. Chem. Soc.*, 28: 1089, 1906), all of whom heated precipitated silica with no other flux than that resulting from the impurities adsorbed during precipitation from aqueous sodium silicate solution. Day and Shepherd could find no evidence for any change in precipitated silica of this type even after it had been heated for a month at 900° C.. Braesco also found that silica gel remained amorphous even when ignited to near 1000° C.. On the other hand, expansion tests made by Houldsworth and Cobb on precipitated silica which had been heated for over 700 hours at 700° C. indicated, but not very definitely, the presence of cristobalite in the α form. The experiments described in this paper make it quite clear from the evidence of powder diffraction photographs that, below 870° C., it is possible to obtain α and β cristobalite as intermediate forms between amorphous silica (vitreous silica or silica gel) and tridymite, thus bringing these transformations into line with Ostwald's principle (*Zeit. Physikal. Chem.*, 22: 289, 1897). The production of cristobalite from vitreous silica in the presence of fluxes below 870° C. has an interesting bearing on the crystallite theory of the glassy state (Randall and Rooksby, *Z. Krist.*, 75: 201, 1930) in so far as it is quite consistent with the ideas contained in that theory. A rather unexpected result was the persistence at room temperature of β or high temperature cristobalite produced from vitreous silica, silica gel and opal. Cristobalite prepared from a specimen of opal, whose diffraction pattern before treatment with a flux consisted of a broad diffuse band

only, was particularly stable. Fenner has observed variations of as much as 50° C. in the inversion temperature of cristobalite prepared at different temperatures and from different sources, the temperature of inversion falling as the temperature of formation is reduced.

In view of Fenner's results, it is not altogether surprising that at the low temperatures at which cristobalite was formed in our experiments, the transition should fail to take place even at room temperature. More remarkable even than the delayed inversion of β cristobalite is the nature of the transition it ultimately undergoes on standing for a period of several months to a year. A specimen photographed in December of 1932 showed the lines of β cristobalite, but after a lapse of about four months it showed indubitably the lines of α tridymite. Although this change was observed on a number of occasions it is a transition of such an unprecedented type that further confirmatory work on individual crystals is desirable.

Since the usual criteria employed in distinguishing the forms of silica from one another—particularly tridymite and cristobalite—are not well adapted for the study of the very fine grained products of the crystallization of amorphous silica under the conditions of the experiments about to be described, the X-ray powder diffraction patterns characteristic of the different modifications were employed as a means for their qualitative detection.

EXPERIMENTAL.

The X-ray examination of all specimens was carried out with the usual Debye-Scherrer camera using filtered $\text{CuK}\alpha_1\alpha_2$ radiation from a Shearer tube operated at 30 kV.. The camera was calibrated in the usual way

with electrolytic copper. Specimens were all reduced to a powder by percussion, then ground in an agate mortar and finally mounted on glass fibres. The heat treatment was in all cases carried out in platinum crucibles uniformly heated in an electric furnace, the temperature of which was measured with a Cambridge compensated pyrometer. At the conclusion of the heating, usually for a period of thirty hours, the flux, potassium chloride or sodium tungstate, was carefully dissolved away, the specimen again reduced to a powder and photographed.

Silica gel was prepared from sodium silicate and hydrochloric acid and subsequently subjected to a prolonged washing. It was dried at 100° C., powdered and then heated at 800° C. for several hours. The source of the vitreous silica was a piece of clear tubing. The opal used was a specimen which showed a broad X ray diffraction band only. Chemically pure potassium chloride and sodium tungstate were employed as fluxes.

Experimental Results.

Photographs of silica gel and vitreous silica showed only the broad band observed by previous workers. The band was not perceptibly sharpened by heat treatment of the material for 30 hours at 810° C. Addition of a flux at this temperature gave rise to a material the powder photographs of which showed patterns identified with cristobalite or tridymite according to the conditions. Vitreous silica so treated gave rise to a mixture of α and β cristobalite while silica gel and opal produced β cristobalite alone. Table I shows the lines obtained from each type of amorphous silica after heat treatment with potassium chloride at 810° C. for thirty hours. It will be noted that the intense (210) and (211) lines of

α cristobalite are absent in the case of treated silica gel and opal while their weakness in the case of vitreous silica seems to indicate a mixture of both α and β cristobalite, the latter predominating.

TABLE I.—*Lines which appear in Diffraction Photographs of Silica after Treatment with various Fluxes.*

| Plane. | No. 1. ¹ | No. 2. ¹ | No. 3. ¹ | β Cristobalite. ² | α Cristobalite. ² |
|--------|---------------------|---------------------|---------------------|---------------------------------------|--|
| (111) | A.U. 4.12 | A.U. 4.13 | A.U. 4.133 | A.U. 4.086 | A.U. 4.05 |
| (210) | 3.18 | — | — | — | 3.15 |
| (211) | 2.89 | — | — | — | 2.85 |
| (220) | 2.513 | 2.516 | 2.514 | 2.514 | 2.48 |
| (113) | 2.230 | — | — | 2.133 | — |
| (222) | 2.086 | 2.051 | 2.062 | 2.043 | 2.025 |
| (133) | 1.652 | 1.610 | 1.614 | 1.624 | 1.612 |
| (224) | 1.502 | — | 1.436 | 1.444 | — |
| (333) | 1.342 | — | — | 1.362 | — |

¹See Nos. 1, 2 and 3 in Table II for further details *re* these substances.

²³For comparison, the spacings of α cristobalite (Barth, *Am. Journ. Science*, **97**: 224, 1932) and β cristobalite (calculated from the results given in a paper by Levin and Ott, *Zeit. Krist.*, **85**: 305, 1933) are shown in the two columns on the right.

A further series of experiments carried out with the two fluxes at different temperatures gave the products listed below in Table II. Table III shows the planar spacings of the lines produced by four specimens (*a*) immediately after their preparation and (*b*) after standing at room temperature from five to twelve months. The two columns on the right show the planar spacings of the lines of α tridymite and α cristobalite for comparison.

DISCUSSION.

On account of the weak birefringence of α cristobalite and the isotropy of both β cristobalite and amorphous

silica, the optical discrimination of one form from another is uncertain, particularly with extremely fine grained material. This may account for the fact that the production of both α and β cristobalite as forms

TABLE II.—*Summary of Results obtained with various Fluxes.*

| Expt. No. | Material. | Temperature. | Flux. | Product. |
|----------------|------------------|-----------------|---------------------------------|--------------------------------|
| 1 | Vitreous Silica. | (800°–810°) | KCl. | $\alpha + \beta$ cristobalite. |
| 2 | Silica gel. | " | " | β cristobalite. |
| 3 | Opal. | " | " | " " |
| 4 | Vitreous Silica. | 840°–850° | " | α tridymite. |
| 5 | Silica gel. | " | " | " " |
| 6 | Opal. | " | " | β cristobalite. |
| 7 ¹ | Opal. | 1000° (c.a.) | " | " " |
| 8 ² | Opal. | 1500° \pm 10° | No Flux. | α cristobalite. |
| 9 | Vitreous Silica. | 840°–850° | NaCl | α tridymite. |
| 10 | Silica gel. | " | " | " " |
| 11 | Opal. | " | " | " " |
| 12 | Vitreous Silica. | " | Na ₂ WO ₄ | " " |
| 13 | Silica gel. | " | " | " " |
| 14 | Opal. | " | " | " " |
| 15 | Vitreous Silica. | 800°–810° | " | " " |
| 16 | Silica gel. | " | " | " " |
| 17 | Opal. | " | " | " " |
| 19 | Vitreous Silica. | 700°–710° | " | " " |
| 20 | Silica gel. | " | " | " " |
| 21 | Opal. | " | " | β cristobalite. |

Time of heating, about 30 hours.

¹Heated 10 hours.

²Heated 2 hours.

intermediate between amorphous silica and tridymite has not been previously noted. While it may be pointed out that the persistence of β cristobalite at room temperature depends upon the temperature to which it has been

heated and the nature of the amorphous silica from which it has been produced, the reason for the persistence is obscure. The β cristobalite which occurs in natural opals has presumably existed through geologic periods. β cristobalite grown from opals, characterised

TABLE III.—*Diffraction Lines which appear in Photographs of various Specimens after Standing Some Months.*

| No. 1. | No. 2. | No. 3. | No. 4. | α Tridymite. ¹ | α Cristobalite. ² |
|---------------|---------------|---------------|---------------|-------------------------------------|--|
| A.U. 4·311 | A.U. 4·358 | A.U. 4·306 | A.U. 4·350 | A.U. 4·29 (220) (040) | A.U. — |
| 4·097 | 4·087 | 4·062 | 4·084 | 4·08 (004) | 4·05 (111) |
| 3·873 | 3·818 | 3·800 | 3·850 | 3·79 (042) (222) | — |
| 3·147 | — | 3·148 | — | — | 3·15 (210) |
| 2·862 | — | 2·859 | — | — | 2·85 (211) |
| — | 2·975 | — | — | 2·96 (224) | — |
| 2·500 | 2·483 | 2·483 | 2·488 | 2·47 (260) | 2·48 (220) |
| 2·227 | 2·317 | 2·317 | 2·313 | 2·28 (422) | — |
| 2·136 | 2·110 | 2·133 | 2·135 | 2·14 (440) | 2·12 (113) |
| — | — | 1·939 | — | — | 1·93 (230) |
| — | 1·851 | 1·867 | — | 1·84 (228) | 1·873 (123) |

¹Gibbs, *Proc. Roy. Soc.*, **356** (1926), 113.

²Barth, *A.J.Sc.*, **97** (1932), 224.

No. 1 is a specimen of α and β cristobalite (Experiment 1, Table II) prepared from vitreous silica, which specimen, after standing for five months, showed the lines of α cristobalite and α tridymite.

No. 2 is a specimen of β cristobalite (Experiment 2, Table II) prepared from silica gel. This specimen, after standing for twelve months, showed the lines of α tridymite only.

No. 3 is a specimen prepared under the same conditions as No. 2. After five months it showed the lines of α cristobalite and α tridymite.

No. 4 is a specimen of β cristobalite prepared from opal (Experiment 3, Table II). This, after five months, showed the lines of α tridymite only.

by a broad diffraction band only, will persist for several months when the temperature of its formation is about 800° C., and the flux used is potassium chloride, whereas cristobalite from opal which had been heated for two hours at 1500° C. inverted immediately on cooling. The

degree of persistence depends also upon the flux used. For example, at 810° C., with potassium chloride as a flux, silica gel gives rise to cristobalite, but with a flux of sodium tungstate tridymite is produced, any cristobalite formed being rapidly inverted to tridymite. The nature of the resulting product depends upon two processes: (a) the growth of cristobalite crystals and (b) the inversion of cristobalite to tridymite, the relative rates of which vary with the flux and the temperature. It has been suggested that the inversion of β cristobalite in opal is inhibited by reason of its being embedded in a glassy matrix (Levin and Ott, *Zeit. Krist.*, 85: 305, 1933). A microscopic examination of our specimens under high magnification revealed a parasitic growth of crystallites on the outside of grains of apparently unchanged material. A thorough grinding of these failed to bring about any inversion. Hence the delayed inversion does not appear to be due to the cause suggested above.

Randall and Rooksby have interpreted the broad X ray diffraction bands produced by vitreous silica as arising from minute crystallites of α cristobalite 10^{-6} – 10^{-7} cm. on an edge. The production of cristobalite from vitreous silica in the presence of a flux can be interpreted as a growth of these sub-microscopic crystals. There is no evidence to show whether this growth occurs by a coalescence of crystallites to form larger ones, or by a process of solution of the smaller but more soluble crystallites in the flux and the subsequent deposition of the dissolved material on the larger of the crystallites originally present. The mosaic structure of crystals (cf. Zwicky, *Proc. Nat. Acad. Sc.*, 15: 816, 1930) could quite conceivably arise as a result of the former mechanism of growth.

The authors wish to thank Professor Eastaugh, of the Technology Department, for the loan of an electric resistance furnace and pyrometers, also Mr. S. Maguire for assistance in the construction of a precision Debye-Scherrer camera. One of us (F.P.D.) is indebted to the University of Sydney for a Science Research Scholarship.

Department of Chemistry,
University of Sydney.

ABSTRACT OF PROCEEDINGS
OF THE
Royal Society of New South Wales.

May 3rd, 1933.

The Annual Meeting, being the five hundred and sixteenth General Monthly Meeting of the Society, was held in the Hall of Science House, Gloucester and Essex Streets, Sydney, at 7.45 p.m.

Professor W. R. Browne, President, in the chair. Thirty-four members and seven visitors were present. The minutes of the general monthly meeting of 7th December, 1932, were read and confirmed.

The President announced the deaths of the following members: Sir Joseph Carruthers, elected in 1920; the Hon. George Frederick Earp, elected in 1919; John Michael Taylor, elected in 1905; and Walter E. Roth, Clarke Medallist (1909).

The President announced that Dr. J. J. C. Bradfield had been created a Companion of the Order of Saint Michael and Saint George by His Majesty the King. A letter was read from Dr. Bradfield thanking the Council for its congratulations in regard to the honour conferred upon him.

The certificates of two candidates for admission as ordinary members were read: one for the second and one for the first time. The following gentleman was duly elected an ordinary member of the Society: Robert Lorimer Corbett.

The Annual Financial Statement for the year ending 31st March, 1933, was submitted to members and, on the motion of Professor Chapman, seconded by Mr. Challinor, was unanimously adopted.

ROYAL SOCIETY OF NEW SOUTH WALES.

Statement of Receipts and Payments for the Year
Ended 31st March, 1933.

GENERAL ACCOUNT.

| RECEIPTS. | | £ | s. | d. | £ | s. | d. |
|---------------------------------------|---------|-----|----|----|--------|----|----|
| Dr. | | | | | | | |
| To Balance—31st March, 1932 | .. .. |  |  |  | 83 | 7 | 2 |
| „ Revenue— | | | | | | | |
| Subscriptions | .. .. . | 515 | 19 | 0 | | | |
| Sundry Receipts | .. .. . | 61 | 13 | 5 | | | |
| Government Subsidy | .. .. . | 200 | 0 | 0 | | | |
| Interest— | | | | | | | |
| Government Bonds and Stock | | | | | | | |
| and Loan | .. .. . | 512 | 17 | 6 | | | |
| | | | | | 1,290 | 9 | 11 |
| „ Royal Society's Fund—Interest Added | .. .. . |  |  |  | 261 | 0 | 1 |
| „ Life Membership Fees | .. .. . |  |  |  | 21 | 0 | 0 |
| „ Science House | .. .. . |  |  |  | 650 | 11 | 8 |
| „ Repayment—Institution of Engineers | .. .. . |  |  |  | 1,000 | 0 | 0 |
| „ Building Investment Loan Fund | .. .. . |  |  |  | 1,091 | 19 | 4 |
| | | | | | £4,398 | 8 | 2 |

| PAYMENTS. | | £ | s. | d. | £ | s. | d. |
|-----------------------------------|---------|-----|----|----|-----|----|----|
| Cr. | | | | | | | |
| By Administrative Expenses— | | | | | | | |
| Salaries and Wages— | | | | | | | |
| Office Salary and Accountancy | | | | | | | |
| Fees | .. .. . | 334 | 10 | 0 | | | |
| Assistant Librarian | .. .. . | 14 | 0 | 0 | | | |
| Caretaker (Cleaning) | .. .. . | 24 | 0 | 0 | | | |
| | | | | | 372 | 10 | 0 |
| Printing, Stationery, Advertising | | | | | | | |
| and Stamps— | | | | | | | |
| Stamps and Telegrams | .. .. . | 44 | 18 | 0 | | | |
| Office Sundries and Stationery | .. .. . | 9 | 15 | 6 | | | |
| Advertising | .. .. . | 10 | 6 | 0 | | | |
| Printing | .. .. . | 63 | 18 | 0 | | | |
| | | | | | 128 | 17 | 6 |
| Rents, Rates, Taxes and Services— | | | | | | | |
| Rent | .. .. . | 228 | 12 | 1 | | | |
| Electric Light and Gas | .. .. . | 11 | 11 | 3 | | | |
| Insurance | .. .. . | 22 | 0 | 4 | | | |
| Telephone | .. .. . | 14 | 3 | 10 | | | |
| | | | | | 276 | 7 | 6 |
| Printing and Publishing Society's | | | | | | | |
| Volume— | | | | | | | |
| Printing, etc. | .. .. . | 435 | 5 | 4 | | | |
| Bookbinding | .. .. . | 38 | 3 | 3 | | | |
| | | | | | 473 | 8 | 7 |
| Library— | | | | | | | |
| Bookbinding | .. .. . | 172 | 8 | 6 | | | |
| Books and Periodicals | .. .. . | 83 | 16 | 7 | | | |
| | | | | | 256 | 5 | 1 |

| | | | | | | |
|---------------------------------|-----|----|---|--|--------|------|
| Sundry Expenses— | | | | | | |
| Repairs | 3 | 11 | 9 | | | |
| Bank Charges .. . | 0 | 1 | 0 | | | |
| Sundries .. . | 37 | 11 | 1 | | | |
| Re-establishment Expenses .. | 7 | 4 | 1 | | | |
| | | | | | 48 | 7 11 |
| „ Interest— | | | | | | |
| Royal Society's Fund .. . | 261 | 0 | 1 | | | |
| Loans .. . | 82 | 5 | 4 | | | |
| | | | | | 343 | 5 5 |
| „ Furniture .. . | | | | | 25 | 2 1 |
| „ Science House .. . | | | | | 510 | 11 8 |
| „ Bonds .. . | | | | | 1,828 | 6 3 |
| „ Walter Burfitt Prize Fund .. | | | | | 50 | 7 6 |
| „ Clarke Memorial Fund .. . | | | | | 0 | 11 6 |
| „ Balance—31st March, 1933— | | | | | | |
| Cash on hand .. . | 1 | 10 | 0 | | | |
| Union Bank of Australia Ltd. .. | 82 | 17 | 2 | | | |
| | | | | | 84 | 7 2 |
| | | | | | £4,398 | 8 2 |

Compiled from the Books and Accounts of the Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D.,

Honorary Treasurer.

(Sgd.) W. PERCIVAL MINELL, F.C.A. (Aust.),

Auditor.

Sydney, 24th April, 1933.

BALANCE SHEET AS AT 31st MARCH, 1933.

LIABILITIES.

| | £ | s. | d. | £ | s. | d. |
|--------------------------------|-------|----|----|---|---------|-------|
| Investment Fund— | | | | | | |
| Clarke Memorial Fund .. . | 1,484 | 19 | 8 | | | |
| Walter Burfitt Prize Fund .. . | 591 | 17 | 3 | | | |
| Investment Fund .. . | 4,107 | 2 | 5 | | | |
| Liversidge Bequest .. . | 572 | 7 | 5 | | | |
| | | | | | 6,756 | 6 9 |
| On Loan .. . | | | | | 1,628 | 17 7 |
| Sundry Liabilities .. . | | | | | 73 | 10 5 |
| Accumulated Funds .. . | | | | | 29,390 | 3 1 |
| | | | | | £37,848 | 17 10 |

ASSETS.

| | £ | s. | d. | £ | s. | d. |
|----------------------------------|----|----|----|---|-------|-----|
| Cash— | | | | | | |
| Union Bank of Australia, Ltd. .. | 82 | 17 | 2 | | | |
| Cash on Hand .. . | 1 | 10 | 0 | | | |
| | | | | | 84 | 7 2 |
| Government Bonds and Stock | | | | | | |
| (Nominal Value £6,500) .. . | | | | | 6,336 | 8 6 |

Science House Management Committee—

| | | | |
|--------------------------------------|--------|----|---|
| Payments to date | 14,533 | 18 | 4 |
| Sundry Debtors— | | | |
| Institution of Engineers | 4,283 | 6 | 8 |
| Sundries | 61 | 19 | 1 |
| For Subscriptions in arrears | 720 | 14 | 0 |
| | <hr/> | | |
| | 5,065 | 19 | 9 |

Library—

| | | | |
|--------------------------------------|---------|----|----|
| Balance—31st March, 1932 | 9,490 | 9 | 2 |
| Add: Expenditure during year | 256 | 5 | 1 |
| | <hr/> | | |
| | 9,746 | 14 | 3 |
| Office Furniture | 1,741 | 9 | 10 |
| Pictures | 180 | 0 | 0 |
| Microscopes | 120 | 0 | 0 |
| Lantern | 40 | 0 | 0 |
| | <hr/> | | |
| | £37,848 | 17 | 10 |

Compiled from the Books and Accounts of the Royal Society of New South Wales, and certified to be in accordance therewith.

(Sgd.) HENRY G. CHAPMAN, M.D.,

Honorary Treasurer.

(Sgd.) W. PERCIVAL MINELL, F.C.A. (Aust.),

Auditor.

Queensland National Bank Chambers,
27 Hunter Street, Sydney,
24th April, 1933.

INVESTMENT FUND.

Statement of Receipts and Payments for the Year
Ended 31st March, 1933.

| Dr. | RECEIPTS. | | | | | |
|-----------------------------------|-----------|----|----|--------|----|----|
| | £ | s. | d. | £ | s. | d. |
| To Balance—31st March, 1932 | | | | 6,525 | 5 | 8 |
| „ Life Membership Fees | | | | 21 | 0 | 0 |
| „ Interest— | | | | | | |
| Clarke Memorial Fund | 57 | 2 | 8 | | | |
| Walter Burfitt Prize Fund | 24 | 14 | 0 | | | |
| Liversidge Bequest | 22 | 0 | 3 | | | |
| Investment Fund | 157 | 3 | 2 | | | |
| | <hr/> | | | 261 | 0 | 1 |
| | | | | <hr/> | | |
| | | | | £6,807 | 5 | 9 |

PAYMENTS.

| Cr. | | | | £ | s. | d. |
|------------------------------------|--|--|--|--------|----|----|
| By Expenditure— | | | | | | |
| Clarke Memorial Fund | | | | 0 | 11 | 6 |
| Walter Burfitt Prize Fund | | | | 50 | 7 | 6 |
| „ Balance—31st March, 1933 | | | | 6,756 | 6 | 9 |
| | | | | <hr/> | | |
| | | | | £6,807 | 5 | 9 |

On the motion of Mr. Penfold, seconded by Mr. Olle, Messrs. W. P. Minell & Co. were duly elected Auditors for the coming year.

The Annual Report of the Council was read and, on the motion of Dr. Noble, seconded by Mr. Olle, was adopted.

REPORT OF THE COUNCIL FOR THE YEAR 1932-33.

(1st May to 26th April.)

The Council regrets to report the loss by death of five ordinary and two honorary members. Nine members have resigned. On the other hand, eleven ordinary members have been elected during the year. To-day (26th April, 1933) the roll of members stands at 288.

During the Society's year there have been eight general monthly meetings and eleven council meetings.

Thirty-four papers were read at the general monthly meetings.

Lecturettes were given at the general monthly meetings in August, September and November, by Messrs. H. B. Carne, M. B. Welch and A. B. Hector, respectively.

Walter Burfitt Prize.—At a special meeting of the Council held on Friday, July 15th, 1932, the Council awarded the Walter Burfitt Prize for 1932 to Charles Halliby Kellaway, M.C., M.D., M.S., Director of The Walter and Eliza Hall Institute of Research in Pathology and Medicine, Melbourne, and on the afternoon of Tuesday, August 16th, members were invited to a special meeting to enable the President to present the prize and medal to Dr. Kellaway.

Clarke Memorial Medal.—At its meeting on Wednesday, March 29th, 1933, the council awarded the Clarke

Memorial Medal to Walter George Woolnough, D.Sc., F.G.S., of the Department of the Interior, Canberra.

Popular Science Lectures.—Four popular science lectures were given, namely:

July 21: "Volcanoes", by Prof. L. A. Cotton, M.A., D.Sc.

September 15: "Geophysical Prospecting", by Major E. H. Booth, M.C., B.Sc., F.Inst.P.

October 20: "The Physiological Basis of Sex Characteristics", by Assoc.-Prof. H. Priestley, M.D., Ch.M.

November 17: "Modernism in Architecture", by James Nangle, O.B.E., F.R.A.S.

Science House.—The council of the Institute of Architects of New South Wales awarded the Sir John Sulman Medal for 1932 to Messrs. Peddle, Thorp and Walker, designers of Science House, Sydney, for the most meritorious building design within the last five years.

The Library.—The donations to the library have been as follows: 120 volumes, 2,564 parts, 90 reports, 2 calendars and 1 map.

During the year the whole of the library has been returned to Science House. It is a matter of regret that it has not been possible to bind many sets of periodicals during the period in which the library was not available to members.

The library of the Society is now under the care of an Honorary Librarian, and an addition has been made to the Society's office staff so that the routine duties of the library may be promptly and efficiently carried out. Most of the volumes have now been classified and the work of bringing the catalogue up to date is in hand. Efforts are being made to cope with the necessary binding and also to complete imperfect volumes by procuring missing parts by purchase or exchange.

Members are reminded that the Royal Society's library is especially well furnished with the publications of

scientific societies in other parts of the world, many of which would otherwise not be available in New South Wales.

Reprints.—Members were notified that in future they would be provided with one hundred (100) copies of reprints of their paper instead of fifty as hitherto, and for copies of over and above one hundred, the following rates would be charged:

| | 50 | 100 | 120 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|------------------|-----|------|------|------|------|------|------|------|------|------|------|
| Per 16 pages | 6/- | 11/9 | 14/- | 17/6 | 23/3 | 28/9 | 34/3 | 39/9 | 45/- | 50/3 | 55/- |
| Per 8 pages | 5/3 | 10/3 | 12/3 | 15/3 | 20/3 | 25/- | 29/9 | 34/6 | 39/- | 43/6 | 48/- |
| Per 4 pages | 4/9 | 9/3 | 11/- | 13/9 | 18/3 | 22/6 | 26/9 | 31/- | 35/3 | 39/3 | 43/- |
| or part thereof. | | | | | | | | | | | |

The following donations were received: 5 volumes, 68 parts and 2 reports.

The President, Professor Browne, then delivered his address.

There being no other nominations, the President declared the following gentlemen to be Officers and Council for the coming year:

President:

R. W. CHALLINOR, F.I.C., F.C.S.

Vice-Presidents:

| | |
|--|--------------------------------------|
| Prof. L. A. COTTON, M.A., D.Sc. | EDWIN CHEEL, F.L.S. |
| Prof. O. U. VONWILLER, B.Sc., F.Inst.P. | Assist.-Prof. W. R. BROWNE, D.Sc. |

Hon. Treasurer:

Prof. H. G. CHAPMAN, M.D.

Hon. Secretaries:

| | |
|-----------------------------------|---|
| C. A. SUSSMILCH, F.G.S., F.S.T.C. | R. J. NOBLE, M.Sc., Ph.D., B.Sc.Agr. |
|-----------------------------------|---|

Members of Council:

| | |
|--|--|
| C. ANDERSON, M.A., D.Sc. | A. R. PENFOLD, F.A.C.I., F.C.S. |
| E. H. BOOTH, M.C., B.Sc., F.Inst.P. | Assoc.-Prof. H. PRIESTLEY, M.D., Ch.M. |
| SIR EDGEWORTH DAVID, K.B.E., C.M.G., D.S.O., F.R.S., B.A., D.Sc. | W. L. WATERHOUSE, M.C., D.Sc.Agr., D.I.C. |
| Prof. J. C. EARL, D.Sc., Ph.D. | Prof. R. D. WATT, M.A., B.Sc. |
| JAMES NANGLE, O.B.E., F.R.A.S. | M. B. WELCH, B.Sc., A.I.C. |

Professor Browne, the outgoing President, then installed Mr. R. W. Challinor as President for the coming year and the latter briefly returned thanks. On the motion of Professor Cotton, supported by Mr. Challinor, a hearty vote of thanks was accorded to the retiring President for his valuable address. Professor Browne briefly acknowledged the compliment.

June 7th, 1933.

The five hundred and seventeenth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-nine members and one visitor were present. The minutes of the general monthly and annual meeting of 3rd May, 1933, were read and confirmed. The President congratulated Sir Edgeworth David on having received the degree of Doctor of Science from the University of Sydney.

The certificates of the following candidates for admission as ordinary members were read: one for the second and five for the first time. The following gentleman was duly elected an ordinary member of the Society: Francis Charles Hancock.

The President announced that the following popular science lectures would be delivered this session:

July 20: "Aborigines of the Australian Desert", by Rev. A. P. Elkin, M.A., Ph.D.

August 17: "Useful Products of the Australian Bush", by A. R. Penfold, F.A.C.I., F.C.S.

September 21: "The Age of the Earth", by G. D. Osborne, D.Sc.

October 19: "The Effects of Radium upon Cancers", by Prof. H. G. Chapman, M.D., B.S.

The following donations were received: 220 parts, 12 volumes and 10 reports.

THE FOLLOWING PAPERS WERE READ:

1. "The Decomposition of Chloroform by Radiation from Radon", by G. Harker, D.Sc.
2. "A Magnetic Survey in the Vicinity of a Granite Batholith", by Edgar H. Booth, M.C., F.Inst.P., and J. M. Rayner, B.Sc., A.Inst.P.

July 5th, 1933.

The five hundred and eighteenth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-two members and two visitors were present. The minutes of the preceding meeting were read and confirmed. The President announced the death of Mr. Edward William Knox, who was elected a member in 1877.

The certificates of nine candidates for admission as ordinary members were read: five for the second and four for the first time. The following gentlemen were duly elected ordinary members of the Society: Arthur Cyril Weeks Mears, John Andrews, Esmond J. Selby, George Hermon Slade and Alan Heywood Voisey.

The following donations were received: 190 parts, 12 volumes and 7 reports.

THE FOLLOWING PAPERS WERE READ:

1. "Bi-Nuclear Isomerism of Diphenyl Type", Part II, by Alice Jean Chalmers, B.Sc., and Francis Lions, B.Sc., Ph.D.
2. "Zierone", by A. E. Bradfield, Ph.D., A. R. Penfold, F.A.C.I. and J. L. Simonsen, D.Sc., F.I.C., F.R.S.
3. "Brown Rot of Fruits and Associated Diseases of Deciduous Fruit Trees", by T. H. Harrison, B.Sc.Agr.

August 2nd, 1933.

The five hundred and nineteenth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-seven members and two visitors were present. The minutes of the preceding meeting were read and confirmed.

A letter was read from the Council of the Royal Society of Tasmania notifying this Society of the death of Mr. Clive Lord.

The certificates of eight candidates for admission as ordinary members were read: four for the second and four for the first time. The following gentlemen were duly elected ordinary members of the Society: Robert Oliver Chalmers, Harold Oswald Fletcher, Herbert John Frost and Arthur Muir Welsh.

The following donations were received: 224 parts, 13 volumes and 9 reports.

Dr. H. G. Chapman gave notice that at the next meeting he would move:

"That five members of the Society be appointed as a committee to consider suggestions by the Council of changes in the Rules of the Society and to make proposals to members for alterations of the Rules of the Society."

THE FOLLOWING PAPER WAS READ:

"The Devonian Formation of the Kandos District of N.S.W."
by C. A. Sussmilch, F.G.S.

LECTURETTE:

"The Cultivation of Mushrooms", by Dr. R. J. Noble.

EXHIBITS:

1. Fossil Bones from Brewarrina, N.S.W., by Dr. C. Anderson.
2. Hair Bezoars in Pigs, Sheep and Cattle, by Mr. J. A. Cresswick.
3. Two medals presented by the Academie des Sciences, Paris: Medaille Lavoisier, 1900, and Medaille Berthelot, 1901.

September 6, 1933.

The five hundred and twentieth General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-seven members and two visitors were present. The minutes of the preceding meeting were read and confirmed.

The certificates of five candidates for admission as ordinary members were read: four for the second and one for the first time. The following gentlemen were duly elected ordinary members of the Society: Arthur Johnson Bedwell, Robert Farquhason Boan, Lyster Waverley Ormsby Martin and Richard George Crafter Roberts.

The President announced that the Liversidge Research Lecture for 1933, entitled "The Function of Phosphates in the Fermentations of Sugar", would be delivered by Professor W. J. Young, D.Sc., M.Sc., of the University of Melbourne, on Wednesday, 8th November, at 8 p.m.

The following donations were received: 8 volumes, 215 parts and 11 reports.

Owing to the illness of Dr. Chapman the following notice of motion was postponed:

"That five members of the Society be appointed as a committee to consider suggestions by the Council of changes in the Rules of the Society and to make proposals to members for alterations of the Rules of the Society."

THE FOLLOWING PAPERS WERE READ:

1. "An Interference Method of Determining Indices of Refraction in the Infra-Red", by H. J. Frost, M.Sc.
2. "The Action of Nitrous Acid on Dimethylaniline", Part I, by J. C. Earl, D.Sc., Ph.D., and Allan William Mackney.

LECTURETTE:

"The Story of Ambergris", by F. R. Morrison, illustrated with lantern slides.

EXHIBIT:

Crimping tools for explosives, by Mr. S. W. E. Parsons.

October 4th, 1933.

The five hundred and twenty-first General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Thirty-two members and one visitor were present. The minutes of the preceding meeting were read and confirmed. The President announced the death of Mr. John Taylor Lingen, who was elected a member in 1883.

The certificates of two candidates for admission as ordinary members were read: one for the second and one for the first time. The following gentleman was duly elected an ordinary member of the Society: Adolph Bolliger, Ph.D.

The following donations were received: 94 parts, 6 volumes and 3 reports.

It was moved by Dr. Chapman, seconded by Dr. H. J. W. Brennand, and carried:

"That five members of the Society be appointed as a committee to consider suggestions by the Council of changes in the Rules of the Society and to make proposals to members for alterations of the Rules of the Society."

It was moved by Dr. Chapman, seconded by Mr. Penfold, that the following members form a sub-committee to consider the proposed amendment of the Rules of the Council, namely, the President, Mr. R. W. Challinor, Messrs. A. D. Olle, A. E. Stephen, J. S. Hodson and H. Finnemore.

This motion was carried unanimously.

THE FOLLOWING PAPERS WERE READ:

1. "The Volumetric Determination of Methylene Blue and Picric Acid", by Adolph Bolliger, Ph.D.
2. "Quantum Numbers and Valency", by L. W. O. Martin, B.Sc.

Addresses on the past activities of the Medical Section of the Royal Society were given by Dr. Cecil Purser and Dr. W. F. Burfitt. Remarks were also made by Dr. G. H. Abbott, who suggested that the Council consider the possibility of re-establishing the medical section, and by Dr. J. A. Dick and by Mr. R. T. Baker.

On the motion of the President a hearty vote of thanks was accorded to the speakers.

November 1st, 1933.

The five hundred and twenty-second General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-six members and two visitors were present. The minutes of the preceding meeting were read and confirmed.

The certificate of one candidate for admission as an ordinary member was read for the second time. The following gentleman was duly elected an ordinary member of the Society: Arthur Percy Penman, B.E.

It was announced that the second Liversidge Research Lecture would be delivered by Professor W. J. Young, D.Sc., M.Sc., entitled "The Functions of Phosphates in the Fermentations of Sugar", on Wednesday, 8th November, at 8 p.m.

It was also announced that the Australian National Research Council had invited the members of the Royal Society to attend the first David Lecture to be delivered by Professor E. W. Skeats, D.Sc., of the University of Melbourne, at Science House, on Friday, 17th November,

at 8 p.m., entitled: "Some Founders of Australian Geology".

The following donations were received: 146 parts, 2 volumes and 47 reports.

THE FOLLOWING PAPERS WERE READ:

1. "The Origin of Modern Mountain Ranges", with special reference to the Eastern Australian Highlands, by E. C. Andrews, B.A., F.G.S.
2. "The Essential Oils of *Eucalyptus micrantha* (De Candolle), including a form rich in Piperitone", Part II, by A. R. Penfold, F.A.C.I., F.C.S., and F. R. Morrison, F.C.S.
3. "The Moisture Equilibrium of Timber in Different Parts of N.S.W.", by M. B. Welch, B.Sc.

LECTURETTE:

"Ape Mentality" (illustrated by lantern slides), by Mr. A. S. Le Souef.

December 6, 1933.

The five hundred and twenty-third General Monthly Meeting was held in the Hall of Science House, Gloucester Street, at 7.45 p.m.

Mr. R. W. Challinor, President, in the chair. Twenty-nine members and one visitor were present. The President offered a welcome to Count Moltke, Danish Consul. The minutes of the 1st November, 1933, were read and confirmed.

The following donations were received: 169 parts, 13 volumes, 8 reports, 17 reprints and 1 calendar.

THE FOLLOWING PAPERS WERE READ:

1. "The Essential Oils of the Genus *Calythrix*", Part I, *Calythrix virgata*, by A. R. Penfold, F.C.S., and F. R. Morrison, F.C.S.
2. "Some Mechanical Properties of Alpine Ash", Part I, *Eucalyptus Delegatensis* (R.T.B.), by M. B. Welch, A.I.C., B.Sc.
3. "The Action of Nitrous Acids on Dimethylaniline", Part II, by Prof. J. C. Earl, D.Sc., Ph.D., and Alan William Mackney.

4. "X Ray Diffraction Studies of the Crystallization of Amorphous Silica", by F. P. Dwyer, M.Sc., and D. P. Mellor, M.Sc.
5. "The Volumetric Micro Determination of Perchlorates with Methylene Blue and Picric Acid", by A. Bolliger, Ph.D.
6. "Note on the Longevity of Spores of the Fungus *Urocystis tritici*", by R. J. Noble, M.Sc., Ph.D.

EXHIBIT:

"Some interesting effects with Newton's Rings", by Prof. O. U. Vonwiller, B.Sc.

On behalf of members of the Society, Mr. Olle wished the President and members of Council the compliments of the season. Mr. Olle drew attention to the need for making the seating accommodation more comfortable, and Mr. Penfold intimated that costs would be a factor of primary importance when this matter should come before the Science House Management Committee for consideration.

At the conclusion, the President wished all the members the compliments of the season.

ABSTRACT OF THE PROCEEDINGS
OF THE
GEOLOGICAL SECTION.

Annual Meeting, April 21st, 1933.

Mr. W. S. Dun was in the chair, and nine members and nine visitors were present.

Professor L. A. Cotton was elected Chairman, and Messrs. H. G. Raggatt and G. D. Osborne Joint Honorary Secretaries for the year.

EXHIBITS:

1. By Mr. W. S. Dunn: Specimens sent by the Geological Survey of India as *Proterotepora Ampla* Lonsdale, and *Eurydesma*, from Goolabgarh Gap, India.
2. By Mr. L. L. Waterhouse: (a) Tuffaceous breccia, from basal Kamilaroi (Upper Marine) rocks, resting on granite, $3\frac{1}{2}$ miles S.S.E. of Cudgegong, N.S.W.; (b) Crinoidal quartzite; (c) Ripple-marked Upper Devonian quartzite, from Cudgegong; (d) Silicified fault breccia from Mullumbimby, N.S.W.
3. By Mr. H. G. Raggatt: Photographs of "Grey Billy" boulders in the high level gravels of the Hunter River at Abbey Green, 3 miles south of Singleton, N.S.W.
4. By Dr. G. D. Osborne: Polished slab of contorted varve-rock from Seaham, N.S.W.

Dr. Ida A. Brown addressed the meeting on "The Lower Palæozoic Sediments of the South Coast, their structure, stratigraphical relationships and suggested correlation with other occurrences in Eastern Australia".

The address was discussed by Professors Cotton and Browne, and Messrs. Andrews, Osborne and Raggatt.

June 16th, 1933.

Professor L. A. Cotton was in the chair, and eleven members and fifteen visitors were present.

EXHIBITS:

1. By Assist.-Prof. W. R. Browne: Two specimens collected by Mr. D. Garretty of stalactitic and stalagmitic (?) chalcedony, associated with calcite from vughs in a dolerite sill near Stanwell Park.
2. By Mr. C. A. Sussmilch: Specimen of a whorl of *Glossopteris* leaves apparently attached to a stem, from Baker's Quarry, East Maitland.
3. By Dr. G. D. Osborne: (a) Recent sand-rock crowded with shells from raised beach at Crawley, near Perth, W.A.; (b) splendid example of cone-in-cone structure from the Newcastle Coal Measures, Newcastle.

A discussion on "The Chronology of Movements of the Strand-line in Eastern N.S.W. in late-Pleistocene and later Geological Time" was opened by Professor Cotton.

Using lantern slides, Professor Cotton first dealt with the rock-platforms between Newcastle and Gerringong. Pointing out their association with sea-worn caves, subdued cliffs and shingle beaches (all of which stand above high-tide level), he emphasized that these platforms were being demolished on their seaward side by wave action.

Two lines of evidence were used to show that the platforms must have been cut below present low-tide level, *viz.*, (a) the evidence of the relations of present-day sea caves to sea-level, and (b) the analogy with uplifted platforms, which beyond all doubt were cut out below low-tide level and uplifted into their present position—*e.g.*, those due to recent earthquakes, some of which show incrustations of coral-growth. Some reference was then made to raised beaches and coastal lagoons.

Passing from a discussion of the evidence of an emergence of the strand, details were given of a number of former strand-lines in eastern N.S.W., which are now submerged. These

facts indicate considerable changes in sea-level. The strand-lines considered may be referred to as (i) a level of about 70 fathoms where shelly sand-rock occurs; (ii) the Port Jackson base-level strand, 260 (?) feet; (iii) the Stockton submerged forest level, 160 feet; (iv) the Narrabeen peat level, 70 feet; (v) the Shea's Creek level, 15 feet.

Professor Cotton next dealt with possible causes of a regional change of sea-level, referring to Daly's Glacial Control Theory and to polar wanderings. As a working hypothesis he made suggestions of a possible correlation between some of the eustatic movements of the sea (as implied in the existence of ancient strands) and the well-known stages of the last phase of the Pleistocene glaciation.

Professor Macdonald Holmes agreed with Professor Cotton on many aspects of the problem, but was inclined to the view that something could be said in favour of the assumption that the rock platforms were developed by the sea at its present level. He made reference to a bench about 20 feet above sea-level which is of fairly widespread occurrence.

Speaking on behalf of Mr. Maze, he described a series of ancient potholes in the Broken Bay area, which were obviously worn out when the sea stood higher than it does at present. These potholes are about 20 feet above mean sea-level.

Mr. Sussmilch drew attention to the widespread nature of the coastal platforms in rocks of differing lithology and diverse structure. He described the association of platforms and raised shingle-beaches in the Port Stephens district, which pointed very strongly to a negative movement of the sea in recent time.

Sir Edgeworth David stressed the fact that portions of the Australian coastline had been much more mobile in late geological time than others, and that in addition to platforms, etc., indicative of a recent retreat of the sea, there were uplifted strands in Victoria and South Australia, in some cases going up to 200 feet above sea-level, while in West Australia there were dune rocks submerged to a depth of at least 300 feet.

The discussion was adjourned to a later meeting.

July 21st, 1933.

Professor Cotton was in the chair, and ten members and eleven visitors were present.

EXHIBITS:

1. By Mr. C. A. Sussmilch: (a) Fossiliferous limestone of Middle Devonian age from Cudgegong district, N.S.W.; (b) photographs of geological interest from the Rylstone-Cudgegong district; (c) nodular masses of quartz-felsite showing concentrically arranged masses of chalcedonic quartz. The origin of the structures is obscure.
2. By Mr. O. Chalmers: Well developed crystal-aggregates of stilbite, and associated subordinate calcite quartz and silicate minerals. Locality, Garrawilla Station, Gunnedah district.
3. By Dr. G. D. Osborne (on behalf of Mr. D. Garretty): Pegmatite vein in granite from Cox's River between Little River and Megalong Creek, showing peculiar cruciform twinning in alkali felspar.
4. By Dr. C. Anderson (on behalf of the Australian Museum): Fossil bones recently found at Cuddie Springs, near Brewarrina, N.S.W. The bones included the atlas vertebra and the tibia and radius of *Diprotodon*; leg bones of a struthious bird; reptilian teeth; some bones apparently belonging to the gigantic extinct lizard, *Megalania*; others of an extinct crocodile.

The discussion adjourned from the last meeting was concluded.

Mr. A. H. Voisey described the coastal physiography of the Kempsey-Trial Bay region, emphasising that there was much evidence supporting the hypothesis that a broad silted estuary had been engrafted to the mainland by a negative movement of the sea of the order of 15 feet.

Professor W. R. Browne made some remarks about the possible correlation of the negative movements of the sea with increase in glaciated areas and then went on to discuss certain physiographic features seen around Sydney and in the Gosforth district of the Hunter Valley.

Mr. J. Andrews discussed the platforms, sea-caves and pot-holes, etc., and was of the opinion that all these features could be developed by the present sea, if special allowance were made for unique features of land-locked bays in certain areas.

August 18th, 1933.

Professor Cotton was in the chair, and six members and two visitors were present.

NOTES AND EXHIBITS:

1. By Mr. C. A. Sussmilch: Specimens of lignitic wood and pyritous or marcasitic Pleistocene sand-rock from a well put down by Davis Gelatine Co. at Botany. The section in the bore pointed to submergence in that area.
2. By Mr. H. G. Raggatt: (a) Gossanous ore with limonite resembling gold, from Mt. Brockwell mine, Burruga; (b) Hornblende rock, from $2\frac{1}{2}$ miles S.E. of Trunkey; (c) Tertiary fossil leaves from a deep lead at Trunkey, N.S.W.
3. By Mr. H. F. Whitworth (on behalf of the Mining Museum): (a) *Cordyceps australis* (a fungoid grub) from Tingha, N.S.W.; (b) "Grey Billy" from near Guyra, with silicified plant rootlets.
4. By Mr. G. F. K. Naylor: (a) Kamilaroi shale from Hartley Vale crowded with *Vertebraria* possessing branching rootlets; (b) *Lepidodendron australe* from the Cookbundoon Mtn., Goulburn district, and Upper Devonian marine fossils from a horizon several hundred feet below the *Lepidodendron* beds; (c) handspecimen showing unconformable relationship between older Palæozoic slate and Kamilaroi breccia, from the Marulan district.
5. By Professor L. A. Cotton: Fragment of meteorite from the Henbury Crater area, Central Australia.
6. By Dr. G. D. Osborne: (a) Suite of specimens from Ragunda, Central Sweden, showing development of hybrid rocks by the injection of quartz dolerite by granitic magma; (b) Pegmatite rich in lithium-bearing minerals, particularly petalite, from Isle of Utö, near Stockholm, Sweden.

September 15th, 1933.

Professor Cotton was in the chair and eight members and eleven visitors were present.

Professor W. R. Browne's Presidential Address to the Royal Society of N.S.W., entitled "An Account of Post-

Palæozoic Igneous Activity in New South Wales", was discussed by Messrs. Sussmilch, Raggatt, Osborne, Mahony and Craft, and Sir Edgeworth David, after Professor Browne had given a comprehensive summary of the address.

The chief contribution to the discussion, by Mr. Sussmilch, was in support of the hypothesis that the alkaline Tertiary rocks of the State are younger than the two basic series of flows and intrusives. Dr. Browne maintained that his placing of this alkaline series as occurring in between the two series of basic rocks was more in accord with the field evidence.

October 20th, 1933.

Professor Cotton was in the chair, and eleven members and thirteen visitors were present.

EXHIBITS:

1. By Dr. G. D. Osborne: Large globular masses of prehnite occurring as vugh-fillings in dolerite at Prospect.
2. By Dr. I. A. Brown: (a) Granite showing glacial striæ from Yosemite region, U.S.A.; (b) tuffaceous rocks from Mt. Baker and Mt. Rainier, U.S.A.

Mr. E. C. Andrews and Dr. Ida A. Brown gave an account of their experiences while attending the Fifth Pacific Science Congress at Victoria and Vancouver, B.C., and of excursions made through the Rocky Mountains in British Columbia and Alberta. Some account was given by Mr. Andrews of the geomorphology and tectonics of the Canadian Rockies, and Dr. Brown described the glaciation and structure of the Yosemite, Mt. Baker and Mt. Rainier districts.

November 24th, 1933.

Professor Cotton was in the chair, and eight members were present.

EXHIBITS:

1. By Dr. G. D. Osborne: A series of specimens taken from top to bottom across a composite sill outcropping at Rudh an Eireannaich, Isle of Skye. The sill is 13 feet thick and consists of marginal basalt and central felsite, and a splendid series of hybrid rocks which developed by reaction between the felsite magma and partially consolidated basalt.
2. By Mr. L. F. Harper: Specimens from the Upper Marine series of Greenwell Point, Shoalhaven River district, in which crystals of quartz, sometimes doubly-terminated, have replaced the calcite of crinoidal remains, especially of crinoid stems.

Dr. A. B. Walkom addressed the Section on the XVIth International Geological Congress, giving a general account of the activities and personnel of the Congress, which was held at Washington, and making special mention of the discussions on Upper Palæozoic Stratigraphy and Palæontology which were held. He also described his travels made partly before and partly after the sittings of the Congress.

ABSTRACT OF PROCEEDINGS
OF THE SECTION OF
PHYSICAL SCIENCE.

OFFICERS:

Chairman: Mr. G. H. Godfrey, M.A.

Hon. Secretary: Dr. W. H. Love.

Committee: Professors O. U. Vonwiller, V. A. Bailey, J. P. V. Madsen, Major E. H. Booth, Dr. G. H. Briggs, Father Wm. O'Leary.

Eleven meetings were held during 1933.

- 26th April, 1933.—Mr. G. H. Godfrey, M.A.: "A Simplified Presentation of the Gauss Theory."
- 10th May, 1933.—Major E. H. Booth: "The Use of the Gradiometer in Determinations of Gravity Gradients."
- 7th June, 1933.—Professor G. H. Briggs: "The Evidence for the Existence of the Positive Electron."
- 21st June, 1933.—Dr. Y. B. F. J. Groeneveld: "Modern Radio Valves and their Applications."
- 5th July, 1933.—Mr. T. D. J. Leech: "Physical Aspect of Aerodynamics."
- 19th July, 1933.—Mr. A. L. Green, M.Sc.: "An Investigation of an Anomalous Case of Radio Propagation in the Neighbourhood of Sydney."
- 2nd August, 1933.—Dr. D. S. Martyn: "The Present State of Radio Investigations."
- 20th September, 1933.—Dr. D. S. Martyn: "Some Aspects of Radio Research in Australia."
- 4th October, 1933.—Professor G. H. Briggs: "Measurements of Relative Velocities of Alpha Particle from Radon, Radium A and Radium C₁."

18th October, 1933.—Dr. G. Builder: "Wireless Echoes of Short Delay."

1st November, 1933.—(a) Assoc.-Professor V. A. Bailey, M.A., D.Phil., F.Inst.P.: "The Study of the Passage of Electric Waves Through the Ionosphere by means of Conformal Representation." (b) Mr. A. L. Green, M.Sc.: "The Application of the Magneto-Ionic Theory to Long Wave Propagation."

ABSTRACT OF PROCEEDINGS
OF THE
SECTION OF INDUSTRY.

OFFICERS :

Chairman: A. D. Olle, F.C.S., A.A.C.I.

Hon. Secretary: H. V. Bettley-Cooke, F.C.S., A.A.C.I.

During the year the following works were visited by the members :

Tuesday, 9th May, 1933.—Messrs. W. Watson & Sons Ltd., X-Ray Laboratory, Watson House, Bligh Street, Sydney.

Tuesday, 13th June.—Messrs. J. Bayley & Sons, Tannery Works, Water Reserve, Botany.

Tuesday, 18th July.—The Shell Oil Company of Australia, Clyde Refinery, Granville.

Tuesday, 8th August.—Messrs. R. Fowler Ltd., Potteries, Fitzroy Street, Marrickville.

Tuesday, 12th September.—The General Post Office, Sydney.

Tuesday, 10th October.—Messrs. John Heine & Son Ltd., Machinery Manufacturers, Leichhardt.

Tuesday, 14th November.—Messrs. John Vicars & Co. Ltd., Woollen Manufacturers, Marrickville.

THE FUNCTION OF PHOSPHATES IN
FERMENTATIONS OF SUGARS.*

By W. J. YOUNG, D.Sc.,

Department of Biochemistry, The University of Melbourne.

(Published as a Supplement to the Journal of the Royal Society of New South Wales, Vol. LXVII, 1933.)

I wish to express my appreciation of the honour which the Royal Society of New South Wales has done me in inviting me to give this the second Liversidge Research Lecture. We owe a debt of gratitude to Archibald Liversidge for the happy thought which inspired him to endow the lectures which bear his name. They help to keep green the memory of one who devoted thirty-five years of his life to furthering the study of chemistry at the University of Sydney, and to whom Science and the Scientific Organisations in Australia, and in New South Wales in particular, owe so much. In his will he directed that the purpose of the lectures should be to encourage research, so that after he himself had gone, he might still aid in inspiring others to investigate new territory in that science to which he acknowledged allegiance.

In my choice of subject I have endeavoured to keep in mind this desire, and propose to discuss a subject which has attracted a great deal of attention from biochemists, and of which our knowledge is still very far from being complete, in the hope that some of my

* Second Liversidge Research Lecture delivered to the Royal Society of New South Wales, November 8, 1933.

audience may perhaps be able to rub clean the glass through which, at present, we see darkly.

During recent years, evidence has been gradually accumulating that when sugars undergo degradation by biological means, phosphoric acid is an essential agent in the reactions which take place.

The discovery of this rôle of phosphate was first observed in the fermentation of sugar to carbon dioxide and alcohol by yeast, and perhaps I may be permitted to give very briefly a few stages in the history of our knowledge of this fermentation.

Although the production of alcoholic liquors goes back beyond recorded history, it was not until 1837 that the vegetable origin of yeast was suspected. In this year three experimenters, quite independently and with different modes of attack, arrived at the conclusion that yeast was a living organism. These were Cagniard Latour, Theodore Schwann, and Kützing, and, as was to be expected, their publications were received with general incredulity.

Chief amongst the opponents of the view were the three great organic chemists of the time, Berzelius, Wöhler, and Liebig, and in a number of the *Annalen* of that period is to be found an elaborate travesty by Wöhler and Liebig, in which the idea is held up to ridicule in what would seem to us rather undignified language.

For twenty years the theory made little headway, but in 1857 was commenced the long and rather bitter controversy between Liebig and Pasteur. The latter had accepted the theory and, in a series of researches extending until 1872, proved beyond doubt that fermentation was produced by the living cell in the course of

its vital functions, and that there could be no fermentation without life.

As early as 1858 Moritz Traube had put forward the theory that all fermentations and putrefactions produced by living organisms were really brought about by enzymes, definite chemical substances elaborated by the cell. Traube was a genius whose ideas, in many ways, were greatly in advance of his times, and, in fact, his idea of fermentation as a series of oxidations and reductions is very much in accordance with our present view.

All attempts to obtain such an enzyme from yeast failed until 1897, when it was successfully accomplished by Edouard Buchner. By grinding the yeast with a mixture of sand and kieselguhr and thus rupturing the cells, he was able to press out their contents, the so-called "Hefepresssaft" or "Yeast Juice", a liquid which fermented sugars to CO_2 and alcohol in the entire absence of living cells. Since then, active preparations have been obtained from yeast in other ways, and the enzymic nature of fermentation has been definitely established.

The next advance was the discovery by Harden and Young that there are two other factors concerned in fermentation. One of these is the coenzyme (cozymase), a dialysable, heat-stable, substance necessary for fermentation, forming with the enzyme (apozymase) the fermenting complex. The other is the part played in fermentation by phosphates, and it is this discovery and the developments arising therefrom which I propose to discuss tonight.

When a soluble phosphate is added to a fermenting mixture of yeast juice and glucose, the rate of fermentation rises, sometimes as much as twenty times; this

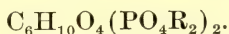
high rate continues for a time, depending on the quantity of phosphate added, and then falls to a rate almost equal to, but generally slightly higher than, that of the original mixture. During this period of increased activity the phosphate unites with the sugar to form esters, and when the rate has again fallen the phosphate is found almost entirely combined in these esters, and in a form not precipitable by magnesium solutions. During this period also the extra carbon dioxide evolved and the alcohol produced are equivalent to the phosphate esterified, in the ratio CO_2 or $\text{C}_2\text{H}_6\text{O}$ to R_2HPO_4 .

This equivalence is of special importance, as it shows that a definite action takes place between the phosphate and the sugar in which the esterification of the sugar with the phosphate is accompanied by the production of an equivalent amount of carbon dioxide and alcohol. If more phosphate be added the phenomenon re-occurs and may be repeated several times, whilst the same action was observed with the three fermentable hexoses, glucose, mannose and fructose.

When the action was discovered in 1909, it was thought that only one ester was formed, a hexose diphosphate, which was isolated by precipitation as the lead salt. Later on Harden and Robison obtained a hexose monophosphate, which Robison has since shown to be a mixture of three monophosphates, and in addition Robison and Morgan have isolated a phosphate derivative of the disaccharide trehalose. The diphosphate is separated from the others through the lower solubility of its barium salt, whilst the others have been separated through the different solubilities of their salts with brucine.

The following compounds have been definitely obtained.

Hexose diphosphate or the Harden and Young ester.

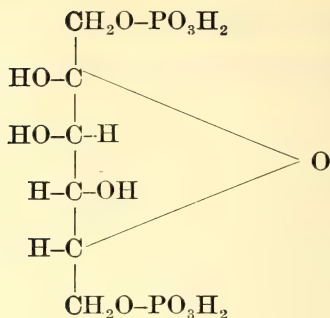


The free acid forms a strongly acid solution, which titrates as a tetrabasic acid with alkali to phenolphthalein, and reduces Fehling's solution. When heated with acid it readily hydrolyses with formation of phosphoric acid and the hexose fructose, so that it is a fructose diphosphate. The same compound is formed from the fermentation of glucose, mannose or fructose, so that in the cases of the aldoses some intramolecular re-arrangement must have taken place. One phosphoric acid group is more easily split off than the other, yielding an intermediate monophosphoric acid ester usually known, after its discoverer, as the Neuberger ester.

When treated with phenyl hydrazine in the cold it forms a hydrazone, and this on heating loses one phosphoric acid group yielding a compound which has been shown to be a derivative of the osazone of a monophosphate of fructose. The importance of this reaction is that it shows that the substance is a hexose diphosphate and not a triose monophosphate, and because it indicates that one of the phosphoric groups is attached to the carbon atom next to the carbonyl group of the fructose.

By conversion into the methyl hexosides and subsequent removal of the phosphoric acid groups by means of the enzyme phosphatase, Robison and Morgan obtained the methyl osides of fructo-furanose or γ fructose. It is probably therefore a derivative of fructose with the phosphoric acid groups in the positions 1 and 6.

This diphosphate is almost invariably formed in the largest amount.

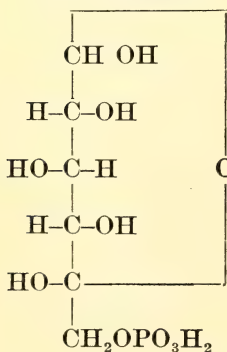


The Hexose monophosphates. $\text{C}_6\text{H}_{11}\text{O}_5\text{PO}_4\text{H}_2$.

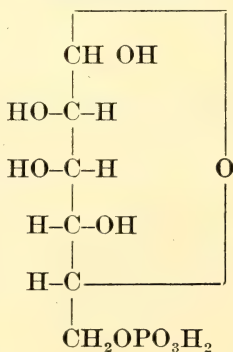
Fructose monophosphate, the Neuberg ester, was first obtained by partial hydrolysis of the diphosphate, but has since been obtained by fermentation. In addition, the aldose ester, generally known as the Robison ester, has now been shown by Robison to be a mixture of monophosphates of both glucose and mannose, and thus the three mono-esters are formed during the fermentation of any one of the three hexoses in the presence of phosphate.

They all yield the same osazone derivative as the diphosphate, the phosphoric group being therefore

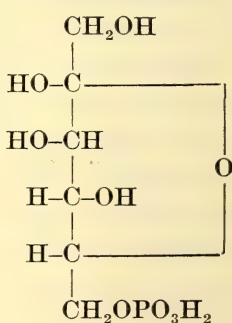
Glucose 6
monophosphate.



Mannose 6
monophosphate.



γ Fructose 6
monophosphate.



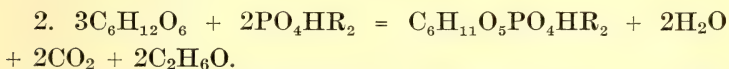
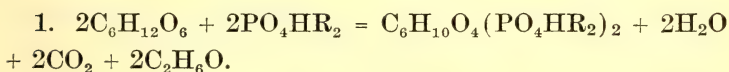
probably on the sixth carbon atom, whilst the fructose monophosphate is a derivative of the γ sugar.

The trehalose compound is only found when the dried preparation "Zymin" is used, and its connection with fermentation is entirely obscure.

Turning now to the rôle of these compounds in alcoholic fermentation, there occur in yeast enzymes termed phosphatases, which hydrolyse the esters with formation of the sugars and free phosphate, so that when the zymase gradually loses its activity, free phosphate accumulates at the expense of the hexose-phosphates.

Summarising the facts, we see that whilst there is still free phosphate present the high rate of fermentation continues, and when all the phosphate has been esterified it sinks to a constant value, which slowly falls off as the enzyme dies out. During this constant rate there are only traces of free phosphate present in the solution, and this only begins to accumulate when the zymase dies out, and then it does so at the expense of the esters.

The reaction between the phosphate and the sugars may be represented in the form of equations:

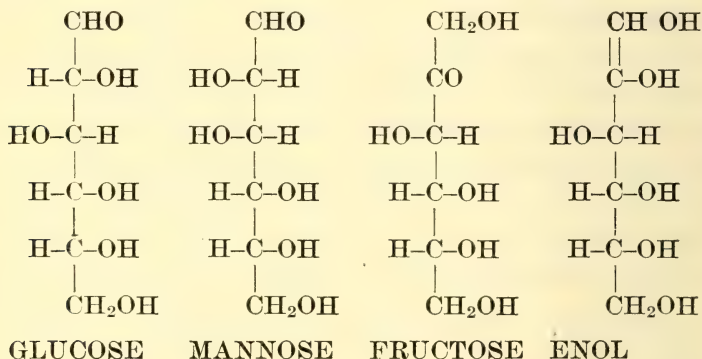


Equation 1 was that originally suggested by Harden and Young when only the diphosphate was known. Equation 2 was added later to take in also the formation of the monophosphates. This assumes that these are formed independently of the diphosphate, and that their formation, like that of the diphosphate, is accompanied by the formation of an equivalent of carbon dioxide and

alcohol, since these products are equivalent to the total phosphate esterified.

The theory that it is the enol form of the hexoses which is fermented was originally suggested by E. F. Armstrong, and again by Harden and Young, when the same diphosphate was found to be formed from all three sugars, and Robison's recent discovery that monophosphates of all three sugars are formed, lends further support to this view.

It will be remembered that glucose, mannose and fructose possess a common enolic form and that any one of the three is converted through this form into an equilibrium mixture of all three.



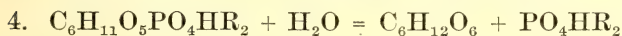
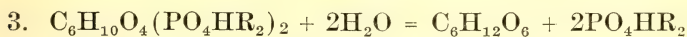
Robison has suggested that one phosphate group first attaches itself to number 1 carbon atom of the enol, and thence is transferred to number 6 carbon, in a similar manner to the wandering of the acetyl group in tetra acetyl glucose under the influence of alkali. The resulting 6 phosphated enol may then in part combine with a second phosphoric group to form fructose diphosphate, but some may pass into an equilibrium mixture of glucose, mannose and fructose monophosphates. In this

way all four esters would be formed from the phosphated enol, CO_2 and alcohol being formed at the same time from more sugar.

On the other hand, it is known that phosphatase acting on the diphosphate removes the phosphoric groups in stages, producing the Neuberg ester as an intermediate, and Meyerhof has recently shown that an extract of animal muscle will convert either the aldose or ketose monophosphates into an equilibrium of both types. It is therefore possible that the diphosphate is first formed and the monophosphates arise by enzymic hydrolysis of this, the removal of the phosphoric group from carbon atom 1 being accompanied by intramolecular change through the enol. This also receives support from the fact that early this year, Robison and Macleod obtained a mixture of aldose and ketose monophosphates by the action of bone phosphatase on the diphosphate.

If this alternative be correct, equation 2 would not be required, since the formation of the monophosphates would not be accompanied by any fermentation products.

To complete the picture of fermentation we require two more equations showing the action of the enzyme phosphatase:



The phosphate set free in these reactions would then once more enter into equations 1 and 2.

Thus when all phosphate has been esterified, the constant rate of fermentation is determined by the rate at which it is again set free in the reactions 3 and 4.

If the fermentation of sugars by yeast can be represented by these equations, it should follow that no action should take place in the absence of phosphate. Hitherto it has

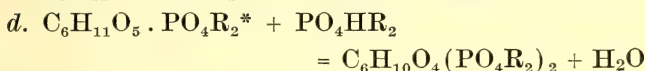
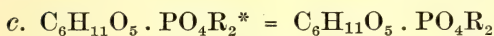
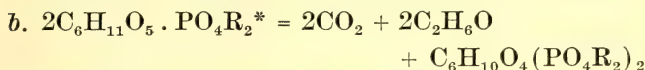
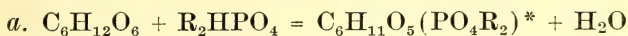
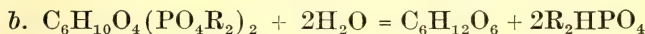
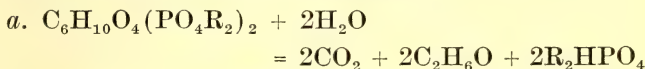
not been found possible completely to free any yeast preparations from phosphate, but in experiments in which it was greatly reduced, fermentation became correspondingly small, and was increased nearly a hundred times by adding phosphate.

There is thus very strong evidence that phosphate is indispensable for alcoholic fermentation.

In the equations which I have given, the hexosephosphates are in no sense intermediate bodies in fermentation, but a coupled reaction is suggested in which the phosphorylation of one molecule of sugar is accompanied by the decomposition of another.

There are other theories which assume these esters to be actual intermediate bodies. The one which has received much support is due to Meyerhof and his associates. According to this, during the period of rapid fermentation, an active form of monophosphate is first formed (equation I, *a*). Part of this then undergoes fermentation at a high rate, the sugar moiety of one molecule decomposing to CO_2 and alcohol, and the phosphoric acid uniting with another molecule to form the diphosphate (equation I, *b*). At the same time some of the active form passes into a stable form, which is the monophosphate of fermentation (equation I, *c*), whilst still another portion is esterified to diphosphate by free phosphate still in the mixture (equation I, *d*).

The hexose diphosphate then undergoes decomposition in two ways. Part is directly fermented (equation II, *a*), giving CO_2 , alcohol and free phosphate, which re-enters the cycle as in equation I, *a*. The rest is hydrolysed into hexose and free phosphate by the phosphatase (equation II, *b*), and these products also enter the cycle as in equation I, *a*.

I. *Phosphate Period.* Rapid Fermentation.

 II. *Ester Period.* Slow Fermentation.


It would take too long to give the evidence upon which this theory is based, but the main criticism brought against it by Harden is that the extra CO_2 and alcohol formed according to I, *b*, should be equivalent to the diphosphate formed in this action alone, and actually less than the total diphosphate formed, since some diphosphate is also formed in I, *d*, without any of these products, whereas, in actual fact, these products are equivalent to the total phosphate esterified, *i.e.*, both mono and diphosphates.

Other theories have prepounded the preliminary formation of a triose monophosphate and a three carbon chain compound; two molecules of the former then condense to form a hexose diphosphate, whilst two of the latter break down to CO_2 and alcohol.

Let us now turn to another biological process in which carbohydrates are degraded anaerobically, and in which phosphates play a part similar to that in alcoholic fermentation, namely, the production of lactic acid during muscular activity in the animal.

* = active form.

The fuel from which animal muscle ultimately obtains its energy is largely carbohydrate, stored in the muscle cells as glycogen. During muscular work some of the glycogen is converted into lactic acid, a change which sets free energy but requires no oxygen, so that a muscle can do a limited amount of work without using oxygen. Subsequently some of the lactic acid or other carbohydrate intermediate is oxidised aerobically, and this action gives the necessary energy to rebuild up glycogen from the rest of the lactic acid and to restore the original condition of the system.

Embden was the first to obtain a hexosephosphate by the action of muscle-juice, and, considering it as a precursor of lactic acid, he called it "lactacidogen".

Since then it has been shown that minced muscle in the presence of sodium fluoride yields a hexose phosphate identical with the diphosphate of yeast fermentation, but in the absence of fluoride a monophosphate is formed, now known to be a mixture of aldose and ketose monophosphates similar to those obtained from yeast juice. Embden's lactacidogen is thus probably a mixture of the monophosphates of glucose, mannose, and fructose, and may arise as the result of partial hydrolysis of the diphosphate.

Muscle mince can readily convert glycogen into lactic acid, but it has no action on hexoses. The direct breakdown of a polysaccharide, built up of glucose units, to lactic acid without an intermediate stage of a hexose, is unthinkable, and it appears probable that the glycogen is first converted into a hexose in a more active form.

This idea is supported by the fact, discovered by Meyerhof, that a solution of the precipitate obtained by adding alcohol to autolysed yeast, enabled the muscle

to produce lactic acid from hexoses. This activator or hexokinase, as it is termed, is thermolabile and is thought to convert hexoses into a more reactive form. In the presence of hexokinase and phosphate, minced muscle acts on sugars with a rapid production of lactic acid accompanied by the esterification of the phosphate, largely to hexose diphosphate. When all the phosphate has been esterified, the rate of acid production falls, but no free phosphate accumulates until all the sugar has been converted into lactic acid.

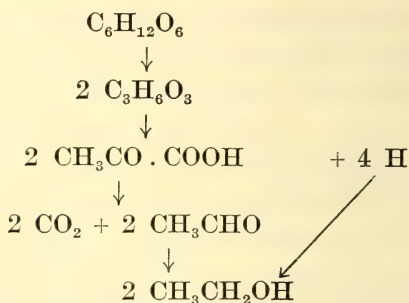
During the rapid initial high rate period, two molecules of phosphate are esterified for every molecule of sugar converted into lactic acid. The similarity of this reaction to that of alcoholic fermentation is at once apparent, and the equations previously given will fit the changes, the CO_2 and alcohol being replaced by lactic acid.

The changes which we have been considering so far are concerned with the first stage in fermentation, during which the hexosephosphate formation appears to be a necessary part, and we have said nothing about the intermediate steps in the change from the six carbon chain of the sugar to the final products, CO_2 and alcohol, or the three carbon compound, lactic acid.

Long before there was any experimental evidence it was believed that the first stage in the degradation of hexoses was the formation of a three carbon compound, and various bodies were suggested as intermediate compounds. In later years, methyl glyoxal has found most favour as the immediate three carbon compound to be formed, but very recent work seems definitely to have ruled out this compound as an intermediate in the fermentation of sugars. It is almost certain that the

next stage is pyruvic acid, and that this is acted upon by the enzyme carboxylase, yielding CO_2 and acetaldehyde, the latter then being reduced to alcohol.

This can be represented in a crude way by the following scheme adapted from Neuberg, which shows the changes without introducing phosphate and as a series of oxidations and reductions:

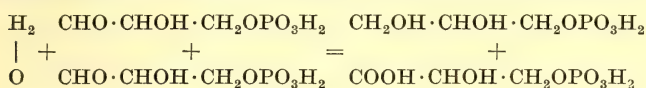


The same scheme will fit the action in muscle, the pyruvic acid in the absence of the carboxylase being itself reduced to lactic acid.

Within the last few months a theory has been put forward by Embden and modified by Meyerhof, dealing with the mechanisms of these later stages in the anaerobic breakdown of carbohydrates, and which is really an extension of the scheme given above. The hexosediphosphate does not exist in quantity either in living yeast or in intact muscle, and Meyerhof considers that the accumulation of this compound in yeast-juice and in minced muscle results from the disorganisation of the cells.

The work of Lohmann had shown that muscle extract will act upon hexose diphosphate and convert some of it into a form more resistant to hydrolysis but with apparently the same composition. From this action Embden and Meyerhof have now obtained two

compounds, one a monophosphate of glyceric acid termed phosphoglyceric acid, and the other α -glycero-phosphoric acid, two compounds which he considers as probable dismutation products from a triose monophosphate.



The phosphoglyceric acid is then broken down to pyruvic acid and free phosphoric acid, and the pyruvic acid reacts with the glycero-phosphoric acid to give lactic acid and possibly a triosemonophosphate, again an oxidation-reduction action.

Embden's scheme may be shown thus:

1. Fructose diphosphate = 2 triose monophosphate = α glycerophosphate + phosphoglyceric.

2. Phosphoglyceric acid = pyruvic acid + phosphoric acid.

3. Pyruvic acid + glycerophosphoric acid = lactic acid + triosephosphate.

Meyerhof has applied the same ideas to the problem of alcoholic fermentation with some variation:

Initial Phase.

A. 1 Hexose diphosphoric acid + 1 glucose + 2 phosphoric acid = 4 triose phosphoric acid = 2 α glycerophosphoric acid + 2 phosphoglyceric acid

B. Phosphoglyceric acid = 2 pyruvic acid + 2 phosphoric acid = 2 acetaldehyde + 2 carbon dioxide + 2 phosphoric acid

Stationary Condition.

C. 2 Acetaldehyde + 1 glucose + 2 phosphoric acid = 2 triose phosphoric acid + 2 acetaldehyde = 2 alcohol + 2 phosphoglyceric acid.

As before, the fructose diphosphate is converted to phosphoglyceric and α glycerophosphoric acids, and the phosphoglyceric acid to pyruvic acid. The enzyme

carboxylase then comes into action and converts the pyruvic acid into CO_2 and aldehyde. The next stage is more difficult to explain since glycerophosphoric acid will not reduce aldehyde in the presence of yeast. He assumes, therefore, that this reduction is brought about by a triose phosphate which is itself at the same time re-oxidised to phosphoglyceric acid.

He divides the fermentation into two phases, the hexose diphosphate being only necessary to start the reaction, and produce the first quantity of triose ester. It is thus only required in traces.

The full account of these theories has not yet reached this country, and I have had to rely on the report in *Nature* of a lecture delivered by Meyerhof at Cambridge. It is, therefore, not safe to submit the theory to criticism, but it does not appear to offer any explanation of the esterification of the phosphate in yeast juice, nor of the equivalence observed in the fermentation products.

Other Actions in Which Phosphates are Concerned.

The fact that many bacteria acting on carbohydrates produce substances similar in type to the products of yeast, would suggest that phosphate might enter into these reactions also.

It is very difficult to obtain bacterial growths in sufficient quantities to filter off and be able to work with the separated organisms on the same scale as with yeast, but there is accumulating evidence that esterification does take place.

Thus Vertranen and his colleagues have shown that when the lactic acid producing organism, *S. lactis*, acts in the presence of phosphate on sugar, some of the phosphate becomes bound, and they obtained small quantities of a monophosphate from the mixture.

Barrenstein and Parry have also obtained a hexose monophosphate from assimilating *Elodea canadensis*.

Last year Jamieson, working in my own laboratory with *Bacillus acidophilus*, found that in the presence of toluene and phosphate, this organism converted glucose to lactic acid, and the free phosphate disappeared in considerable quantity. When the action ceased, the phosphate was gradually set free again, and could also be recovered at any time by hydrolysis with acids.

It thus seems very probable that the mechanisms of yeast fermentation and of muscle action on carbohydrates will throw light on the manner in which carbohydrates are decomposed in the living world.

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